USEPA/PAPER INDUSTRY COOPERATIVE DIOXIN STUDY
"THE 104 MILL STUDY"
STATISTICAL FINDINGS AND ANALYSES

July 13, 1990

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Office of Water Regulations and Standards
401 M Street, S.W.
Washington, D.C. 20460

USEPA/PAPER INDUSTRY COOPERATIVE DIOXIN STUDY

"THE 104 MILL STUDY"

STATISTICAL FINDINGS AND ANALYSES

EXECUTIVE SUMMARY

This report describes statistical analyses of the data from the "104 Mill Study." This study was the result of a cooperative agreement between EPA and the U.S. paper industry. The purpose of the study was to characterize the 104 U.S. mills that practiced chlorine bleaching of chemically produced pulps in mid to late 1988. The scope of the study was developed by EPA and industry, and the study was managed by the National Council of the Paper Industry for Air and Stream Improvement, Inc. (NCASI), with EPA overview. The data collected included measurements of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) and 2,3,7,8-tetrachlorodibenzofuran (TCDF) concentrations in three export vectors (pulp, sludge, and effluent); and information on wastewater treatment, bleaching, and manufacturing processes. More information was available for kraft mills (155 each lines) than sulfite (18 bleach lines); therefore, some statistical findings are reported for only kraft mills. The statistical findings are:

1. The detected concentration values of TCDD/TCDF were best approximated by lognormal distributions, estimated separately for each of the export vectors: pulp, sludge, and effluent.

2. Analysis of field and laboratory duplicates indicated excellent agreement between duplicate measurements of TCDD/TCDF concentrations. As a consequence, analytical measurement variability is a very small portion of the total variability in the TCDD/TCDF data.

3. The reported detection levels for the non-detected measurements of TCDD/TCDF demonstrate that the target detection level of 10 parts per quadrillion (ppq) for effluent measurements is achievable.

. Estimates of the daily total mass output rates of TCDD/TCDF at U.S. leached pulp mills were 0.004 lbs/day for TCDD and 0.032 lbs/day for TCDF.

Output rates for individual mills varied substantially; however, the per averages were 0.00005 lbs of TCDD and 0.00048 lbs of TCDF exported dai pulp, sludge, and treated effluent.

5. The relative amounts of TCDD/TCDF partitioned to each of the three export vectors (pulp, sludge, and effluent) were highly variable among mills.

6. Significantly more TCDD/TCDF was exported at kraft mills than sulfite mills.

7. Mills using Activated Sludge (ACT) wastewater treatment systems exported somewhat less effluent-based TCDD/TCDF mass on average and significantly more sludge-based TCDD/TCDF mass than mills using Aerated Stabilization Basins (ASB). The difference in sludge exports can be partially attributed to the fact that ACT sludge samples in the 104 Mill Study consisted of combined primary and secondary sludges. Those from ASB systems consisted only of primary sludg

8. Total Suspended Solids (TSS) concentrations in ACT systems was found be significantly higher than the TSS concentrations of ASB systems at k mills.

9. When ACT and ASB-type kraft mills were combined, a weakly correlated positive trend was observed between effluent TCDD/TCDF and TSS levels, and a weakly correlated negative trend was observed between TSS and sludge TCDD/TCDF. For kraft mills using only ACT treatment, higher TSS levels were associated with higher sludge-based TCDD/TCDF exports but lower effluent-based TCDD/TCDF exports.

10. Linear regressions of the TCDD/TCDF export rates fit to bleaching measures at each mill (including application rates of bleaching and chemical extraction agents) were found to be poor predictors of individual kraft mill outputs.

11. Greater chlorine usage in kraft mills was found to be statistically associated with higher formation rates of TCDD/TCDF.

12. Increased substitution of chlorine dioxide for chlorine in the C-stage kraft mills was correlated with slight reductions in TCDD/TCDF formation.

13. Higher chlorine multiples during C-stage bleaching were weakly associated with higher TCDD/TCDF mass formation in kraft mills.

14. Kraft mills that used oxygen delignification in the bleaching process exhibited somewhat lower rates of TCDD/TCDF formation than mills that did not use such methods.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF FIGURES

LIST OF FIGURES (Continued)

1. INTRODUCTION

In October 1987, the U.S. Environmental Protection Agency (EPA) and the U.S. Pulp and Paper Industry jointly released preliminary results from a screening study that provided the first comprehensive results on the formation and discharge of chlorinated dibenzo-p-dioxins (CDDs) and dibenzofurans (CDFs) from pulp and paper mills (1). This screening study of five bleached kraft mills ("Five Mill Study") confirmed that the pulp bleaching process was primarily responsible for the formation of CDDs and CDFs. The partitioning of these compounds between the bleached pulp, wastewater treatment sludge, and final wastewater effluent was found to be highly variable among the mills. The study results also indicated that 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) and 2,3,7,8-tetrachlorodibenzofuran (TCDF) were the principal CDDs and CDFs formed. The final Five Mill Study report was published in March 1988 (2).

To provide EPA with more complete data on the release of these compounds by the U.S. paper industry, an agreement was reached in April 1988 between EPA and the industry to conduct a second study to characterize the 104 U.S. mills that practiced chlorine bleaching of chemically produced pulps (3). The scope of the study was developed by EPA and industry, and the study was managed by the National Council of the Paper Industry for Air and Stream Improvement, Inc. (NCASI), with EPA overview. The data from this study provided an estimate of the release of TCDD and TCDF in three environmental export vectors (i.e., bleached pulp, sludge, and effluent) from the U.S. Pulp and Paper Industry as of mid- to late 1988.

This section presents the major features of the study design, including the field sampling program, the analytical program, and data handling; and a profile of the industry at the time the study was conducted, comprising pulping and bleaching characteristics, bleach line chemical usage during sampling, and wastewater treatment.

The remainder of the report provides details of the statistical analyses and study results, and consists of the following sections:

- Section 2, summary of the findings
- Section 3, characterization of the TCDD/TCDF concentration data
- Section 4, analysis of duplicate samples
- Section 5, partitioning of TCDD/TCDF mass rates into mill exports
- Section 6, analysis of total suspended solids
- Section 7, modeling of TCDD/TCDF formation in terms of mill operating parameters

A listing of the data used in the analyses is also provided in appendix A. This report and a separate summary document were prepared independently by EPA. The paper industry, through NCASI, has also prepared a report of the 104 Mill Study (4). Preliminary study results were presented by EPA and NCASI in September 1989 (5) and will be published in Chemosphere. This report includes data received by EPA from NCASI as of April 1990 and comprises more than 98 percent of the data required by the study objectives.

When reviewing the study results, it is important to keep in mind that the principal objective of the 104 Mill Study was to characterize exports from the 104 mills in terms of TCDD and TCDF. The study was not designed to address mechanisms of formation of these compounds or to determine the best technologies for treating these compounds in wastewaters. Nonetheless, the study results permit some useful observations in these areas as well.

1.1 STUDY FEATURES

All U.S. pulp and paper mills where chemically produced wood pulps are bleached with chlorine and chlorine derivatives were included in the Agreement for the 104 Mill Study (3). Although mills included in the Five Mill Study were not resampled for the 104 Mill Study, TCDD/TCDF data and mill operating and wastewater treatment information from the Five Mill Study have been included in this analysis. Consolidated Paper independently conducted a study at its Wisconsin Rapids, Wisconsin mill. Due to differences in sampling and analytical protocols, the data for TCDD/TCDF from this mill were not included. However, mill characteristics and wastewater treatment information for Consolidated Paper are included in the industry profile presented in subsection 1.2.

1.1.1 Field Sampling Program

The Agreement for the 104 Mill Study required that each significant export vector (fully bleached pulp, wastewater sludge, and final wastewater effluent) be sampled and that the samples be composited over a 5-day period (3). In most cases, the composite samples consisted of up to eight aliquots obtained throughout the sampling day. Nearly all sampling was performed by mill personnel following guidance established by NCASI. In a few cases, NCASI personnel conducted the sampling. The sampling protocols closely followed those established for the Five Mill Study (2).

The pulp samples taken were of the highest brightness pulp produced at each bleach line. At mills with two bleach lines where hardwood and softwood pulps are bleached separately, separate hardwood and softwood composite pulp samples were collected. At mills with a single bleach line where both hardwood and softwood pulps are bleached (i.e., a swing line), sampling was conducted intermittently to ensure that the 5-day composite samples were composed only of hardwood or softwood pulp. A few bleach lines processed mixtures of hardwood and softwood pulps. The composite samples from these lines were classified by the percent of softwood pulp in the mixture.

Sludge samples consisted only of those sludges removed from the wastewater treatment system and disposed of in landfills, by incineration, or by other methods. For mills with Activated Sludge Wastewater Treatment (ACT), the sludge samples generally consisted of combined primary and secondary sludge; for mills with Aerated Stabilization Basins (ASB), only primary sludges were sampled. In most cases, the sludges were dewatered prior to offsite disposal; however, several primary sludges were collected in a low consistency slurry form.

More than 90 sampled effluents were collected from mills with biological treatment. For eight mills, the samples consisted of partially treated effluents prior to discharge to municipal wastewater treatment plants. Two mills with direct ocean discharges provided samples of untreated effluents. Another untreated effluent was sampled at a mill that used a percolation pond for wastewater disposal.

This sampling scheme generated over 400 samples for isomer-specific TCDD and TCDF analyses. About 80 additional samples were collected as part of the quality assurance/quality control (QA/QC) plan. These samples were analyzed as field duplicates and/or included in native spike determinations. The data is listed in Appendix A. In addition, mill operators were required to provide process operating data for bleacheries and wastewater treatment plants. These data were collected to document operation of the processes at the time of sampling.

1.1.2 Analytical Program

The Brehm Laboratory at Wright State University (WSU), Dayton, Ohio, performed analytical methods development work for isomer-specific determinations of TCDD and TCDF in pulp and paper mill matrices and completed analyses of all samples for the Five Mill Study (2). Analytical work for the present study was conducted by Enseco-California Analytical Laboratories (CAL) in West Sacramento, California, and WSU. Enseco-CAL conducted most of the sludge and effluent analyses, while WSU analyzed most of the pulp samples.

The analytical methods used in the 104 Mill Study were consistent with the screening study protocols established for the Five Mill Study (2). Analytical objectives for target detection levels for TCDD and TCDF were 1 ng/kg (parts per trillion [ppt]) for sludges and pulps, and 0.01 ng/kg (ppt) for wastewater effluents. The Agreement specified identification and quantitation criteria for TCDD/TCDF and required that NCASI manage QA/QC programs for the study. NCASI staff performed and coordinated sample preparation, submitted samples to the analytical laboratory, and reviewed laboratory data reports. Nearly all analytical results met the QA/QC objectives established for the study. Several samples required re-analysis to obtain valid data; however, the proportion of such samples was less than 6 percent of the total.

1.1.3 Data Handling

To ensure consistent reporting of bleach plant and wastewater treatment information, NCASI developed specific forms for mill personnel to report bleach line operating characteristics, bleach line chemical applications, and wastewater treatment operations. Copies of these forms, as well as schematic diagrams of the bleacheries and wastewater treatment facilities, were provided to EPA by NCASI for most mills. For those few mills which requested confidential treatment of certain data, the forms were submitted directly to EPA by mill operators. NCASI submitted final analytical results to EPA as they were developed in conformance with the QA/QC protocols specified in the Agreement (3).

EPA and NCASI independently developed data summaries in spreadsheet format to characterize bleach line operating characteristics; mass flow rates of bleached pulp, wastewater sludge, and wastewater effluent; and mass flows of TCDD and TCDF estimated in mill exports. The respective spreadsheet entries were compared several times and corrections made as appropriate. Prior to conducting detailed statistical analyses, EPA had a contractor further compare the spreadsheets against the original report forms. All discrepancies were resolved and the spreadsheets updated. New databases were then created by uploading the data from the spreadsheets to the EPA mainframe computer.

1.2 INDUSTRY PROFILE

At the time the 104 Mill Study field program was underway (mid- to late 1988 for most mills), the U.S. Pulp and Paper Industry was characterized by limited application of those pulping and bleaching practices demonstrated to have the potential to reduce formation of TCDD/TCDF. Since that time, many mill operators have initiated programs to institute improved pulping and bleaching technologies and operating practices. This industry profile, however, does not reflect any changes made by U.S. paper mills since the end of 1988.

1.2.1 Pulping and Bleaching

Tables 1-1 and 1-2 present the industry profile for pulping and bleaching of those mills included in the study. This segment of the U.S. industry comprises 86 kraft pulping mills, 16 sulfite mills, 1 soda mill, and 1 mill with both kraft and sulfite pulping. More than half of the bleach lines at kraft mills are used for bleaching softwoods exclusively and 40 percent for bleaching hardwoods. The balance of the bleach lines are either swing lines or used to bleach hardwood/softwood pulp mixtures. For sulfite mills, half the bleach lines are used for softwood pulps, nearly 40 percent for hardwood pulps, and the balance for mixed pulps.

1.2.2 Bleach Line Chemical Usage

Table 1-3 summarizes the number and percentage of bleach lines with oxygen delignification systems and other chemical usage in pre-bleaching and final bleaching. The data were provided by mill operators during the sampling surveys. During that period, the industry was characterized by low utilization of oxygen delignification, relatively low utilization of oxygen reinforced extraction, low utilization of peroxide reinforced extraction, and relatively high utilization of hypochlorite in both pre-bleaching and final bleaching.

The status of bleachery operations in the U.S. industry in mid- to late 1988 with respect to chlorine usage and chlorine dioxide substitution is summarized in Table 1-4. Note that about 35 percent of the kraft mill bleach lines were operated with no chlorine dioxide in the C-Stage, and less than 2 percent of the kraft mill bleach lines had chlorine dioxide substitution rates greater than 50 percent.

Table 1-5 presents a summary of chlorine multiples (Kappa factor) determined for kraft and sulfite bleach lines at the time of sampling. The chlorine multiple is the ratio of the amount of active chlorine used in pulp bleaching in the C-Stage to the amount of lignin contained in brownstock or oxygen delignified pulp as characterized by the Kappa number. Eleven percent

TABLE 1-1. INDUSTRY PROFILE - PULPING

Type	Number of Mills
Kraft	86
Sulfite	16
Kraft and Sulfite	1
Soda	1
Total	104

TABLE 1-2. INDUSTRY PROFILE - BLEACHING

Woodtype	Number of Bleach Lines		
	Kraft	Sulfite	Soda
Hardwood	67	7	1
Softwood	89	9	-
Mixed HW/SW	9	2	-
Total	165	18	1

Note: Kraft hardwood and softwood bleach line data include 14 swing lines counted as both hardwood and softwood lines.

TABLE 1-3. INDUSTRY PROFILE - BLEACH LINE CHEMICAL USAGE

Chemical Usage	Number of Bleach Lines (%)		
	Kraft	Sulfite	Soda
Oxygen Delignification	7 (4.2)	- (0)	- (0)
Pre-bleaching			
C-Stage Cl_2	165 (100)	16 (89)	1 (100)
C-Stage ClO_2	105 (64)	1 (5.6)	1 (100)
E-Stage O_2	78 (47)	4 (22)	1 (100)
E-Stage NaOCl	47 (28)	1 (5.6)	- (0)
E-Stage H_2O_2	2 (1.2)	1 (5.6)	- (0)
Final Bleaching			
ClO_2	147 (89)	4 (22)	1 (100)
NaOCl	90 (55)	14 (78)	- (0)
H_2O_2	25 (15)	1 (5.6)	- (0)

TABLE 1-4. STATUS OF U.S. BLEACHERY OPERATIONS: C-STAGE CHLORINATION AND CHLORINE DIOXIDE SUBSTITUTION

Kraft Mill Bleach Lines

Chlorine Application		ClO_2 Substitution	
Lbs Cl_2/Ton ADBSP	Bleach Lines	Percent	Bleach Lines
< 40	15	0	59
40-60	22	< 5	16
60-80	32	5-10	41
80-100	36	10-20	33
100-120	28	20-30	9
120-140	16	30-40	1
> 140	16	40-50	3
		50-60	1
		60-70	1
		> 70	1
TOTAL	165	TOTAL	165

Sulfite Mill Bleach Lines

< 40	2	0	17
40-60	1	< 5	1
60-80	2	> 5	0
80-100	6		
100-120	3		
120-140	4		
> 140	0		
TOTAL	18	TOTAL	18

Notes: Bleachery operations for swing lines were counted twice, separately for hardwood and softwood pulps.
ADBSP - Air-dried brownstock pulp.

TABLE 1-5. C-STAGE CHLORINE MULTIPLE (KAPPA FACTOR)

Chlorine Multiple	Number of Bleach Lines: Kraft	Sulfite
< 0.10	4	2
0.10 - < 0.15	15	1
0.15 - < 0.20	51	6
0.20 - < 0.25	54	3
0.25 - < 0.30	17	-
> 0.30	14	6
TOTAL	155	18

Notes: Chlorine multiple was computed from active chlorine (Cl_2 and ClO_2) applied in the C-Stage. Chlorine multiples could not be computed for 10 kraft mill bleach lines because of incomplete data.

of the sampled bleach lines were operated with average chlorine multiples less than 0.15.

1.2.3 Wastewater Treatment

The status of wastewater treatment provided at the 104 paper mills is summarized in Table 1-6. The industry standard consists of primary treatment followed by secondary biological treatment. Eight mills discharge to publicly owned treatment works (POTWs) after primary treatment, and two have no treatment. Wastewaters from one mill are disposed of in a percolation pond. About 35 percent of kraft mills have ACT and more than half have ASB. For sulfite mills, nearly 70% have ACT while almost 20% use ASB.

TABLE 1-6. INDUSTRY PROFILE - WASTEWATER TREATMENT

	Number of Mills			
Treatment Type	Kraft	Sulfite	Soda	Total
ACT	32	11	-	43
ASB	45	3	1	49
Discharge to POTW	7	1	-	8
Discharge to Other Mill WWTP	-	1	-	1
Percolation Pond	1	-	-	1
No Treatment	2	-	-	2
TOTAL	87	16	1	104

Note: The mill with kraft and sulfite pulping was listed as a kraft mill for purposes of this table.

2. SUMMARY OF STATISTICAL FINDINGS

The following discussion summarizes the statistical findings from the 104 Mill Study of U.S. bleached pulp mills. The conclusions are necessarily limited in scope, due to the design of the study. More information was available for kraft mills than sulfite; therefore, some statistical findings are reported only for kraft mills. The results do provide, though, the basis for several useful observations.

2.1 CHARACTERIZING TCDD/TCDF CONCENTRATION DATA

Examination of the laboratory analyses of samples collected at each mill indicated that the detected concentration values of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) and 2,3,7,8-tetrachlorodibenzofuran (TCDF) were best approximated by lognormal distributions, estimated separately for each of the export matrices -- pulp, sludge, and effluent. A number of non-detected measurements were also reported in the data. Analysis of the mass formation rates of TCDD/TCDF required that values be associated with these non-detects. For the purposes of this study, such measurements were assigned a value equal to half the detection level.

This step allowed non-detect samples to be used in a reasonable and consistent manner without distorting the basic findings: (1) the vast majority of all samples had detectable concentrations, with only 15 percent of all TCDD samples and 4 percent of TCDF samples reported as non-detects, (2) the ratio of detectable levels of TCDF to TCDD was fairly consistent from mill to mill, yet less than 4 percent of all the samples were reported as non-detects for <u>both</u> TCDD and TCDF, (3) every mill was found to have detectable levels of TCDD/TCDF in at least one of the export vectors.

Setting non-detect values to half the detection level also represented a compromise between underestimation (assigning non-detect values to zero) and overestimation (assigning non-detect values to the detection level) of the unknown actual concentrations.

2.2 VARIABILITY IN DUPLICATE SAMPLE ANALYSES

Approximately 30 percent of all the samples were classified as field sample duplicates or lab duplicate splits. Analysis of these duplicate samples for each matrix (effluent, pulp, and sludge) indicated excellent agreement between duplicate measurements of TCDD/TCDF concentrations. Most sample correlations between pairs of duplicate measurements were found to above 0.95. Consequently, the proportion of total variability in TCDD/TCDF levels that could be attributed to field sampling protocol or analytical technique was in all cases small relative to other sources of variation. In the worst case observed, analytical measurement error was still less than 12 percent of the total variability in TCDF concentrations.

2.3 DETECTION LEVELS FOR NON-DETECTED MEASUREMENTS

The reported detection levels for non-detected measurements of TCDD/TCDF demonstrate that the laboratories were capable of achieving the target detection levels of 10 parts per quadrillion (ppq) for effluent measurements.

2.4 TOTAL MASS FORMATION ESTIMATES OF TCDD/TCDF

By combining the TCDD/TCDF concentration data with mill production rates of pulp, sludge, and effluent, rates of TCDD/TCDF mass formation were computed for the export matrices at each mill. Estimates of the daily total mass output rates of TCDD/TCDF at U.S. bleached pulp mills were 0.004 lbs/day for TCDD and 0.032 lbs/day for TCDF. Output rates for individual mills varied substantially; however, the per mill averages were 0.00005 lbs of TCDD and 0.00048 lbs of TCDF exported daily in pulp, sludge, and treated effluent.

2.5 VARIABILITY IN PARTITIONING OF TCDD/TCDF TO DIFFERENT EXPORT MATRICES

The relative amounts of TCDD/TCDF partitioned to pulp, sludge, or effluent vectors were not found to be consistent from mill to mill, but highly variable. While some mills partitioned less than 10 percent of their total TCDD/TCDF mass to effluent, effluent-based TCDD/TCDF accounted for more than 80 percent of the exports at other mills. The variability in partitioning of pulp and sludge export vectors was similar. Among the least extreme cases (middle 50 percent of all mills), the relative percentage of TCDD/TCDF exported to specific matrices differed by more than 30 percent from mill to mill.

2.6 DIFFERENCES DUE TO PULPING AND WASTEWATER TREATMENT

Comparisons showed that significantly more TCDD/TCDF was exported at kraft mills than sulfite mills for each matrix type. Differences also emerged between wastewater treatment types Aerated Stabilization Basins (ASB) and Activated Sludge Wastewater Treatment (ACT). There was evidence that mills using ACT exported somewhat less effluent-based TCDD/TCDF mass on average and significantly more sludge-based TCDD/TCDF mass than mills using ASB systems. The difference in sludge exports can be partially attributed to the fact that ACT sludge samples in the 104 Mill Study consisted of combined primary and secondary sludges. Those from ASB systems consisted only of primary sludge.

2.7 RELATIONSHIPS BETWEEN WASTEWATER TREATMENT AND TOTAL SUSPENDED SOLIDS

Further investigation was made of the relationships between TCDD/TCDF mass exports in sludge and effluent vectors, wastewater treatment types, and levels of total suspended solids (TSS) from kraft mills. When ACT and ASB-type kraft mills were combined, a weakly correlated positive trend was observed between effluent TCDD/TCDF and TSS levels, and a weakly correlated negative trend was observed between TSS and sludge TCDD/TCDF. For kraft mills using only ACT treatment, higher TSS levels were associated with higher sludge-based TCDD/TCDF exports but lower effluent-based TCDD/TCDF exports.

2.8 RELATIONSHIPS BETWEEN TCDD/TCDF FORMATION AND MILL OPERATING CHARACTERISTICS

When the effects of mill bleaching procedures upon TCDD/TCDF formation in kraft mills were analyzed, correlations between mass export rates of TCDD/TCDF and a series of mill parameters, including application rates of bleaching and extraction chemical agents, were generally low. Consequently, linear regressions of the TCDD/TCDF export rates fit to bleaching measures at each mill were found to be poor predictors of individual mill outputs.

2.9 EFFECTS OF CHLORINE APPLICATION IN PRE-BLEACHING

Significant positive trends were observed between average TCDD/TCDF formation in kraft mills and the rate of application of chlorine (Cl_2) in the C-Stage bleaching process. Greater chlorine usage was thus found to be statistically associated with higher formation rates of TCDD/TCDF. It was also found that increased substitution of chlorine dioxide for chlorine in the C-Stage was correlated with slight reductions in TCDD/TCDF formation. Lack of chlorine dioxide use at high rates of substitution during the study sampling period precluded more detailed analysis of the impact of chlorine dioxide (ClO_2) substitution.

2.10 EFFECT OF THE CHLORINE MULTIPLE

Variables measuring the chlorine multiple (also known as the Kappa factor) during C-stage bleaching were positively associated with TCDD/TCDF mass formation in kraft mills, though the resulting correlations were fairly weak. These results imply that on average, when accounting for lignin content, greater use of chlorine in the C-stage was linked weakly to higher formation of TCDD/TCDF.

2.11 USE OF OXYGEN IN THE BLEACHING PROCESS

Kraft mills that used oxygen delignification in the bleaching process exhibited somewhat lower rates of TCDD/TCDF formation than mills that did not use such methods. The same mills, however, also tended to have high substitution rates of ClO_2 for Cl_2, so it is not clear whether the lower export rates of TCDD/TCDF observed at these mills were attributable to oxygen delignification, chlorine dioxide substitution, or some combination of both.

2.12 DIFFERENCES IN WOOD TYPES

Larger amounts of chlorine were generally applied to softwood pulps than to hardwood pulps per ton of pulp processed in kraft mills, and the average Kappa numbers of softwood pulps were significantly higher than those of hardwood pulps. These findings are consistent with known differences in bleaching practices for hardwood versus softwood pulps.

3. CHARACTERIZATION OF THE TCDD/TCDF CONCENTRATION DATA

This section characterizes the laboratory data reported to the U.S. Environmental Protection Agency (EPA) concerning the concentration levels of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) and 2,3,7,8-tetrachlorodibenzofuran (TCDF) found in samples of pulp, sludge, and effluent collected as part of the 104 Mill Study. The reported data were examined for distributional properties and skewness and fit to appropriate probability distributions. The sensitivity of subsequent analyses to non-detected measurements was assessed. Attempts were made to handle non-detected samples in a reasonable and consistent manner that would not distort the basic findings.

After examining the raw concentrations, the appropriateness of fitting TCDD and TCDF values to separate lognormal distributions was investigated. Only detected concentration values were examined for distributional fit. Approximately 15 percent of all the TCDD analyses and 4 percent of the TCDF analyses were recorded as non-detects. The detection levels for these non-detected measurements are summarized in Table 3-1.

3.1 VARIABILITY IN DETECTION LEVELS

The variation in detection levels reported for non-detects (Table 3-1) can be attributed to several sources. Reliable measurement of TCDD/TCDF levels is matrix-dependent, a fact reflected in the analytical detection level targets for effluent samples, which were different from the targets for pulp and sludge. In addition, the presence of other compounds can make identification of TCDD/TCDF difficult without dilution of the sample, leading to detection levels that can be sample-specific.

The Enseco-California Analytical Laboratory (CAL) and the Wright State University (WSU) lab each analyzed at least some samples from every matrix. Almost 80 percent of the pulp samples were analyzed at WSU, while 89 percent of the effluent samples and 81 percent of the sludge samples were handled by CAL. Since these laboratories used somewhat different clean-up and routine handling

TABLE 3-1. DETECTION LEVELS FOR NON-DETECT SAMPLES

Pulp Non-Detects (ppt)	TCDD	TCDF
N of Cases	39	11
Minimum	0.100	0.100
Maximum	4.900	6.800
Mean	0.667	1.218
Standard Dev.	0.805	1.880
Median	0.500	0.800

Sludge Non-Detects (ppt)	TCDD	TCDF
N of Cases	4	0
Minimum	0.300	--
Maximum	3.000	--
Mean	1.650	--
Standard Dev.	1.121	--
Median	1.650	--

Effluent Non-Detects (ppq)	TCDD	TCDF
N of Cases	30	11
Minimum	3.000	2.100
Maximum	17.000	10.000
Mean	7.733	5.764
Standard Dev.	2.789	2.458
Median	7.500	5.800

procedures, it would be possible to expect different detection levels for samples of a given matrix, depending on which lab performed the analysis.

Overall, the analytical objectives of the 104 Mill Study were generally met. Ninety-two percent of non-detect pulp samples had reported detection levels at or below the 1 part per trillion (ppt) target level established in the Agreement (3). All but four sludge samples had detectable concentrations of TCDD/TCDF. Of these four, one was below the target detection level. For effluent samples, the target level of 10 parts per quadrillion (ppq) was achieved in the analyses of 83 percent of the TCDD non-detects and 100 percent of the TCDF non-detects (Figures 3-1 and 3-2).

3.2 FITTING OF DETECTED CONCENTRATIONS

For the detected sample concentrations, graphical goodness of fit was done via lognormal probability plots (base 10 scale), matching the ordered concentration levels against the expected values of a lognormal distribution. When data are well-approximated by a lognormal density, such plots closely resemble a straight line. Examination of the plots showed that the data were adequately fit by lognormal densities estimated separately for each export matrix of pulp, effluent, and sludge samples (plots are located in appendix B).

As noted, only detected values were used to characterize the distributions of TCDD/TCDF concentrations within each matrix. Estimates for non-detects measurements, however, were needed for later stages of the analysis. To handle non-detects in a simple, consistent manner, non-detect values were assigned as half the reported detection level.

Decision on the treatment of non-detected samples depends upon the purposes of the analysis and the specific nature of the data. In this case, over 96 percent of all the quantitated samples in the 104 Mill Study exhibited detectable levels of either TCDD or TCDF, including at least one matrix export from every mill. Since the ratio of detectable levels of TCDF to TCDD was fairly consistent from mill to mill, there was evidence that non-detected samples contained small positive concentrations of TCDD/TCDF. Setting non-detects to zero would tend

FIGL 3-1

SAMPLE CUMULATIVE DISTRIBUTION GRAPH
EFFLUENT TCDD DETECTION LEVELS

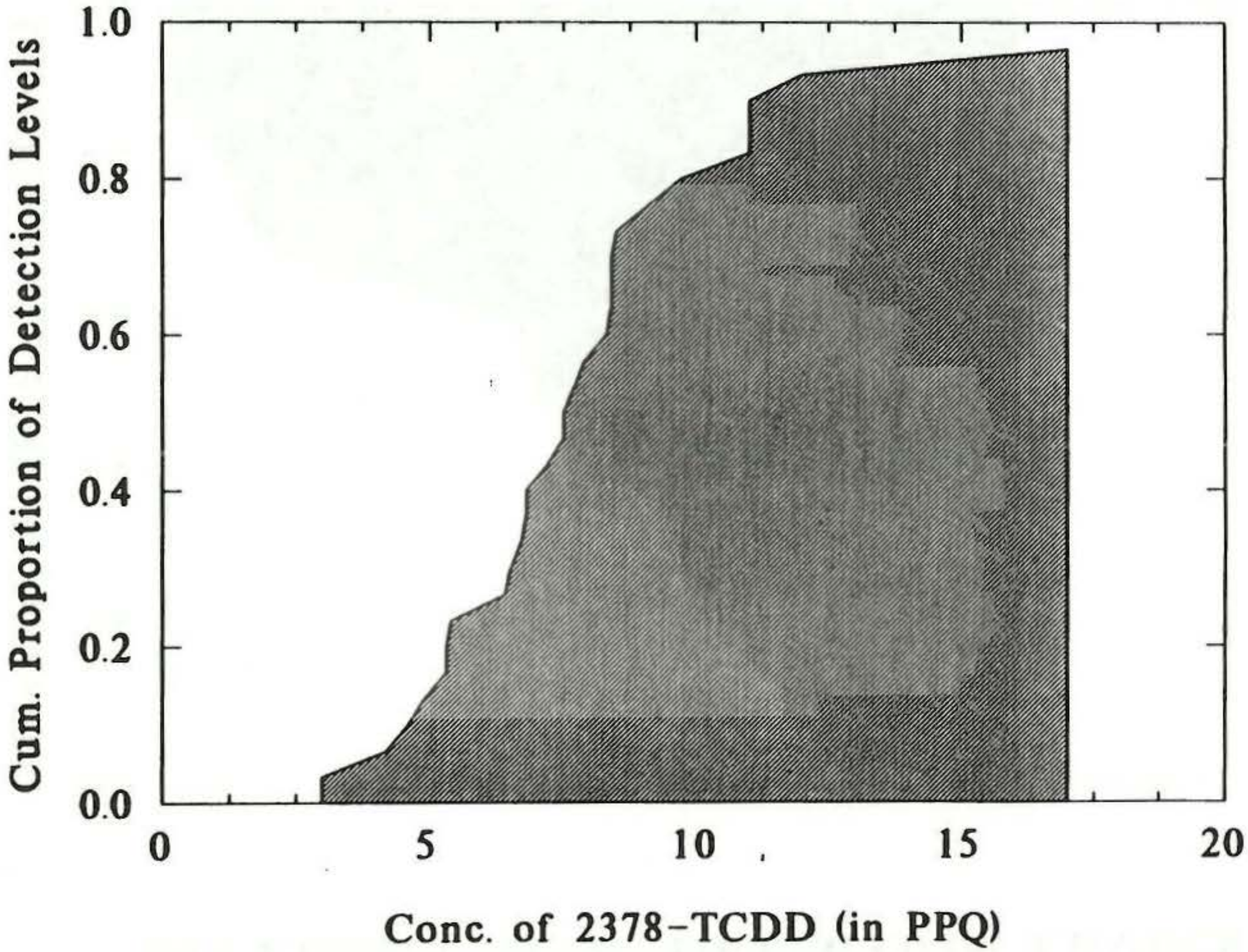
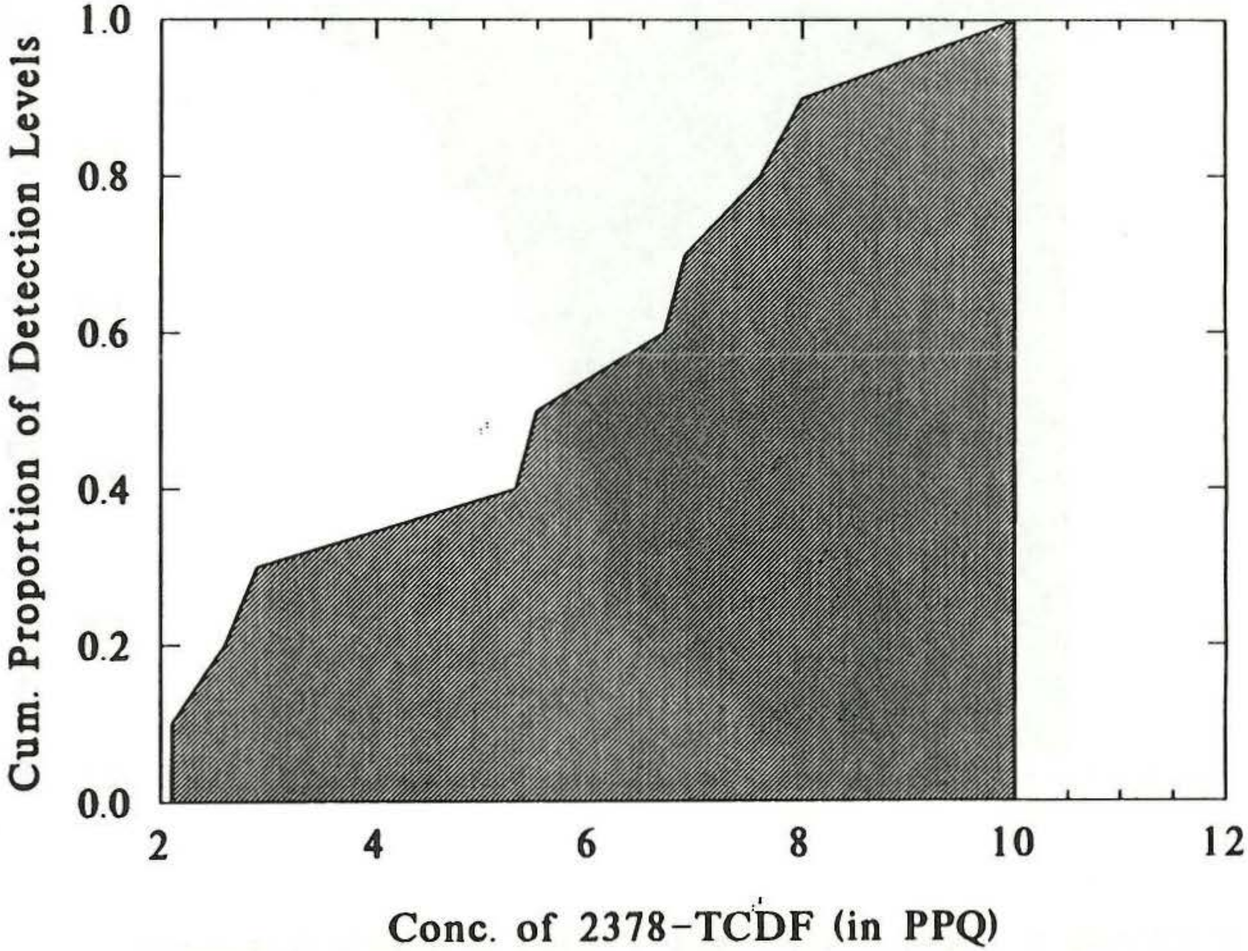


FIGURE 3-2

SAMPLE CUMULATIVE DISTRIBUTION GRAPH
EFFLUENT TCDF DETECTION LEVELS



to underestimate the true concentrations of TCDD/TCDF. On the other hand, EPA has frequently assigned non-detects to their detection levels, since the detection levels provide an upper bound on the actual concentrations present in non-detected samples.

Setting non-detects to half the detection level is an arbitrary choice, but has been used with environmental data to steer a "middle ground" between over- and underestimation of the unknown concentrations within non-detected samples (6,7). Since the proportion of non-detects among the total sample set was relatively small, the choice to set non-detects at half the detection level was also considered unlikely to seriously affect the final TCDD/TCDF mass loadings computed at each paper mill.

To illustrate this last point, Tables 3-2 and 3-3 present summary statistics of the TCDD/TCDF concentrations under different assumptions concerning the values of non-detects; the first section summarizes detected concentration values only, while the others report all TCDD/TCDF concentrations after setting non-detects equal to either half the detection level, zero, or the detection level. Some differences are apparent in the tables, particularly for pulp and effluent TCDD samples at sulfite mills, but overall, the discrepancies were judged to be relatively minor when weighed against the precision of the data as a whole.

In summary, the detected concentration values of TCDD/TCDF were found to be best approximated by lognormal distributions, which were estimated separately for each of the export matrices: pulp, sludge, and effluent. Non-detects were consistently assigned to half the detection level in all subsequent analyses.

TABLE 3-2. DESCRIPTIVE STATISTICS FOR TCDD CONCENTRATIONS

DETECTED SAMPLES ONLY

Matrix	N	Mean	Std	Minimum	Maximum	Lower Quartile	Median	Upper Quartile	90th Percentile
All Samples									
Pulp (ppt)	179	10.44	12.85	0.400	116.00	3.50	6.00	14.00	23.00
HW	65	7.48	9.53	0.400	55.70	2.80	4.10	7.70	17.00
SW	100	12.02	14.73	0.500	116.00	4.12	7.60	14.75	26.90
Sludge (ppt)	114	86.32	169.43	0.400	1390.00	10.63	34.00	96.50	188.00
Effluent (ppq)	103	68.22	100.80	3.100	640.00	15.00	30.00	82.00	172.00
Kraft Samples									
Pulp (ppt)	173	10.46	13.00	0.400	116.00	3.55	6.00	13.50	24.20
HW	62	7.50	9.68	0.400	55.70	2.80	4.00	7.70	17.00
SW	98	12.11	14.86	0.500	116.00	4.17	7.60	15.05	27.00
Sludge (ppt)	94	100.86	183.08	0.900	1390.00	14.00	39.00	105.25	203.00
Effluent (ppq)	90	75.85	105.67	3.100	640.00	16.00	35.00	95.07	189.00
Sulfite Samples									
Pulp (ppt)	4	6.22	5.93	2.000	15.00	2.38	3.95	12.35	15.00
HW	3	7.13	6.92	2.000	15.00	2.00	4.40	15.00	15.00
SW	1	3.50	.	3.500	3.50	3.50	3.50	3.50	3.50
Sludge (ppt)	18	13.22	16.61	0.400	58.00	3.42	4.75	15.25	48.10
Effluent (ppq)	12	13.33	5.71	4.500	23.00	9.72	12.00	18.00	22.70

NON-DETECTS = 1/2 DETECTION LEVEL

Matrix	N	Mean	Std	Minimum	Maximum	Lower Quartile	Median	Upper Quartile	90th Percentile
All Samples									
Pulp (ppt)	217	8.66	12.29	0.050	116.00	1.90	4.70	11.00	21.00
HW	84	5.84	8.91	0.050	55.70	0.70	3.30	6.00	16.00
SW	114	10.59	14.32	0.100	116.00	3.20	6.30	13.25	25.50
Sludge (ppt)	118	83.42	167.23	0.150	1390.00	8.77	32.00	95.25	185.60
Effluent (ppq)	133	53.70	92.63	1.500	640.00	6.15	19.00	63.00	138.00
Kraft Samples									
Pulp (ppt)	194	9.36	12.68	0.050	116.00	2.40	5.15	12.00	22.00
HW	74	6.32	9.25	0.050	55.70	1.57	3.50	6.25	16.50
SW	104	11.43	14.68	0.250	116.00	3.92	6.50	14.00	26.50
Sludge (ppt)	97	97.77	181.03	0.700	1390.00	13.50	37.40	104.50	197.00
Effluent (ppq)	107	64.47	100.34	1.500	640.00	9.20	24.00	81.00	164.00
Sulfite Samples									
Pulp (ppt)	18	1.63	3.56	0.100	15.00	0.15	0.30	1.47	5.46
HW	8	2.81	5.15	0.100	15.00	0.16	0.32	3.80	15.00
SW	8	0.82	1.14	0.150	3.50	0.19	0.32	1.10	3.50
dge (ppt)	19	12.53	16.42	0.150	[illegible]	3.20	4.70	14.00	47.00
luent (ppq)	25	8.16	6.41	2.100	[illegible]	3.27	4.50	12.00	20.20

TABLE 3-2. DESCRIPTIVE STATISTICS FOR TCDD CONCENTRATIONS (CONTINUED)

NON-DETECTS = 0

Matrix	N	Mean	Std	Minimum	Maximum	Lower Quartile	Median	Upper Quartile	90th Percentile
All Samples									
Pulp (ppt)	217	8.61	12.33	0.000	116.00	1.90	4.70	11.00	21.00
HW	84	5.79	8.94	0.000	55.70	0.70	3.30	6.00	16.00
SW	114	10.55	14.35	0.000	116.00	3.20	6.30	13.25	25.50
Sludge (ppt)	118	83.39	167.25	0.000	1390.00	8.77	32.00	95.25	185.60
Effluent (ppq)	133	52.83	93.12	0.000	640.00	5.75	19.00	63.00	138.00
Kraft Samples									
Pulp (ppt)	194	9.33	12.70	0.000	116.00	2.40	5.15	12.00	22.00
HW	74	6.28	9.28	0.000	55.70	1.57	3.50	6.25	16.50
SW	104	11.41	14.70	0.000	116.00	3.92	6.50	14.00	26.50
Sludge (ppt)	97	97.74	181.05	0.000	1390.00	13.50	37.40	104.50	197.00
Effluent (ppq)	107	63.80	100.76	0.000	640.00	9.20	24.00	81.00	164.00
Sulfite Samples									
Pulp (ppt)	18	1.38	3.65	0.000	15.00	0.00	0.00	0.50	5.46
HW	8	2.67	5.23	0.000	15.00	0.00	0.00	3.80	15.00
SW	8	0.44	1.24	0.000	3.50	0.00	0.00	0.00	3.50
Sludge (ppt)	19	12.53	16.42	0.000	58.00	3.20	4.70	14.00	47.00
Effluent (ppq)	25	6.40	7.82	0.000	23.00	0.00	0.00	12.00	20.20

NON-DETECTS = DETECTION LEVEL

Matrix	N	Mean	Std	Minimum	Maximum	Lower Quartile	Median	Upper Quartile	90th Percentile
All Samples									
Pulp (ppt)	217	8.71	12.26	0.100	116.00	1.95	4.70	11.00	21.00
HW	84	5.89	8.88	0.100	55.70	1.00	3.30	6.00	16.00
SW	114	10.64	14.28	0.200	116.00	3.20	6.30	13.25	25.50
Sludge (ppt)	118	83.45	167.22	0.300	1390.00	8.77	32.00	95.25	185.60
Effluent (ppq)	133	54.58	92.18	3.000	640.00	8.75	19.00	63.00	138.00
Kraft Samples									
Pulp (ppt)	194	9.39	12.66	0.100	116.00	2.40	5.15	12.00	22.00
HW	74	6.35	9.23	0.100	55.70	1.57	3.50	6.25	16.50
SW	104	11.45	14.67	0.500	116.00	3.92	6.50	14.00	26.50
Sludge (ppt)	97	97.81	181.01	0.900	1390.00	13.50	37.40	104.50	197.00
Effluent (ppq)	107	65.15	99.95	3.000	640.00	11.00	24.00	81.00	164.00
Sulfite Samples									
Pulp (ppt)	18	1.88	3.49	0.200	15.00	0.30	0.60	2.15	5.46
HW	8	2.95	5.07	0.200	15.00	0.32	0.65	3.80	15.00
SW	8	1.20	1.19	0.300	3.50	0.37	0.65	2.20	3.50
Sludge (ppt)	19	12.54	16.41	0.300	58.00	3.20	4.70	14.00	47.00

TABLE 3-3. DESCRIPTIVE STATISTICS FOR TCDF CONCENTRATIONS

DETECTED SAMPLES ONLY

Matrix	N	Mean	Std	Minimum	Maximum	Lower Quartile	Median	Upper Quartile	90th Percentile
All Samples									
Pulp (ppt)	206	89.53	251.14	0.600	2620.00	5.67	19.50	60.22	164.20
HW	79	55.83	123.24	0.800	661.00	4.10	15.00	49.00	108.00
SW	108	117.69	326.52	0.600	2620.00	6.32	22.50	64.27	230.60
Sludge (ppt)	115	697.73	2012.20	0.700	17100.00	34.50	107.00	624.00	1582.00
Effluent (ppq)	127	412.30	1108.94	2.800	8400.00	36.00	82.00	320.00	864.00
Kraft Samples									
Pulp (ppt)	187	89.58	259.27	0.600	2620.00	6.80	21.00	59.00	148.20
HW	72	56.08	124.43	0.800	661.00	5.32	17.50	49.75	107.10
SW	99	117.98	337.06	0.700	2620.00	7.30	26.00	63.90	185.00
Sludge (ppt)	97	796.45	2174.35	2.400	17100.00	35.10	161.00	675.50	1728.00
Effluent (ppq)	104	476.19	1214.02	4.200	8400.00	42.25	98.00	359.75	1150.00
Sulfite Samples									
Pulp (ppt)	14	89.36	166.95	1.100	449.00	2.70	6.35	100.25	429.00
HW	5	73.42	139.82	1.100	323.00	4.10	9.90	174.50	323.00
SW	7	125.43	207.71	1.400	449.00	2.10	6.30	409.00	449.00
Sludge (ppt)	16	98.63	143.34	0.700	584.00	26.75	63.00	85.75	350.20
Effluent (ppq)	21	112.26	194.37	2.800	840.00	16.00	35.00	120.00	376.00

NON-DETECTS = 1/2 DETECTION LEVEL

Matrix	N	Mean	Std	Minimum	Maximum	Lower Quartile	Median	Upper Quartile	90th Percentile
All Samples									
Pulp (ppt)	216	85.40	245.95	0.050	2620.00	4.22	18.00	58.50	154.20
HW	84	52.52	120.20	0.150	661.00	3.13	14.50	46.50	106.50
SW	113	112.50	320.07	0.050	2620.00	5.55	19.00	61.45	207.20
Sludge (ppt)	115	697.73	2012.20	0.700	17100.00	34.50	107.00	624.00	1582.00
Effluent (ppq)	138	379.66	1069.30	1.050	8400.00	26.00	69.50	312.50	841.00
Kraft Samples									
Pulp (ppt)	192	87.26	256.25	0.350	2620.00	5.70	20.00	59.00	144.90
HW	74	54.58	123.05	0.350	661.00	3.97	15.50	49.25	106.50
SW	102	114.52	332.62	0.400	2620.00	6.52	22.50	60.22	176.60
Sludge (ppt)	97	796.45	2174.35	2.400	17100.00	35.10	161.00	675.50	1728.00
Effluent (ppq)	111	446.39	1180.41	2.750	8400.00	37.00	82.00	340.00	1064.00
Sulfite Samples									
Pulp (ppt)	19	65.90	147.50	0.050	449.00	-0.45	3.10	9.90	409.00
HW	8	45.99	112.27	0.150	323.00	0.30	4.10	21.97	323.00
SW	9	97.58	188.18	0.050	449.00	0.77	3.80	207.70	449.00
Sludge (ppt)	16	98.63	143.34	0.700	584.00	26.75	63.00	85.75	350.20
luent (ppq)	25	94.55	182.20	1.050	0.00	6.00	29.00	91.00	328.00

TABLE 3-3. DESCRIPTIVE STATISTICS FOR TCDF CONCENTRATIONS (CONTINUED)

NON-DETECTS = 0

Matrix	N	Mean	Std	Minimum	Maximum	Lower Quartile	Median	Upper Quartile	90th Percentile
All Samples									
Pulp (ppt)	216	85.38	245.96	0.000	2620.00	4.22	18.00	58.50	154.20
HW	84	52.50	120.21	0.000	661.00	3.13	14.50	46.50	106.50
SW	113	112.48	320.08	0.000	2620.00	5.55	19.00	61.45	207.20
Sludge (ppt)	115	697.73	2012.20	0.700	17100.00	34.50	107.00	624.00	1582.00
Effluent (ppq)	138	379.43	1069.38	0.000	8400.00	26.00	69.50	312.50	841.00
Kraft Samples									
Pulp (ppt)	192	87.25	256.25	0.000	2620.00	5.70	20.00	59.00	144.90
HW	74	54.57	123.05	0.000	661.00	3.97	15.50	49.25	106.50
SW	102	114.51	332.62	0.000	2620.00	6.52	22.50	60.22	176.60
Sludge (ppt)	97	796.45	2174.35	2.400	17100.00	35.10	161.00	675.50	1728.00
Effluent (ppq)	111	446.16	1180.50	0.000	8400.00	37.00	82.00	340.00	1064.00
Sulfite Samples									
Pulp (ppt)	19	65.85	147.53	0.000	449.00	0.00	3.10	9.90	409.00
HW	8	45.89	112.32	0.000	323.00	0.00	4.10	21.97	323.00
SW	9	97.56	188.19	0.000	449.00	0.70	3.80	207.70	449.00
Sludge (ppt)	16	98.63	143.34	0.700	584.00	26.75	63.00	85.75	350.20
Effluent (ppq)	25	94.30	182.34	0.000	840.00	6.00	29.00	91.00	328.00

NON-DETECTS = DETECTION LEVEL

Matrix	N	Mean	Std	Minimum	Maximum	Lower Quartile	Median	Upper Quartile	90th Percentile
All Samples									
Pulp (ppt)	216	85.41	245.95	0.100	2620.00	4.22	18.00	58.50	154.20
HW	84	52.54	120.19	0.300	661.00	3.13	14.50	46.50	106.50
SW	113	112.51	320.06	0.100	2620.00	5.55	19.00	61.45	207.20
Sludge (ppt)	115	697.73	2012.20	0.700	17100.00	34.50	107.00	624.00	1582.00
Effluent (ppq)	138	379.89	1069.22	2.100	8400.00	26.00	69.50	312.50	841.00
Kraft Samples									
Pulp (ppt)	192	87.27	256.25	0.600	2620.00	5.70	20.00	59.00	144.90
HW	74	54.59	123.04	0.700	661.00	3.97	15.50	49.25	106.50
SW	102	114.54	332.61	0.700	2620.00	6.52	22.50	60.22	176.60
Sludge (ppt)	97	796.45	2174.35	2.400	17100.00	35.10	161.00	675.50	1728.00
Effluent (ppq)	111	446.62	1180.32	4.200	8400.00	37.00	82.00	340.00	1064.00
Sulfite Samples									
Pulp (ppt)	19	65.96	147.48	0.100	449.00	0.90	3.10	9.90	409.00
HW	8	46.10	112.22	0.300	323.00	0.60	4.10	21.97	323.00
SW	9	97.60	188.17	0.100	449.00	0.85	3.80	207.70	449.00
Sludge (ppt)	16	98.63	143.34	0.700	584.00	26.75	63.00	85.75	350.20
Effluent (ppq)	25	94.81	182.06	2.100	840.00	6.25	29.00	91.00	328.00

4. ANALYSIS OF FIELD AND LAB DUPLICATE SAMPLES

Section 4 examines the variability in measurements of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) and 2,3,7,8-tetrachlorodibenzofuran (TCDF) reported for sets of duplicate samples. Concentration values for duplicate measurements were plotted against each other to assess the degree of agreement, and the total variability in duplicate samples was analyzed to determine what fraction could be attributed to measurement error or differences in sampling and analytical protocols.

The fact that the distributions of TCDD/TCDF concentration values could be analyzed as approximately lognormal was important in two ways: to concretely characterize the data from the 104 Mill Study and to analyze the variability in TCDD/TCDF concentrations attributable to duplicate field sampling or repeated laboratory tests. Of the 500 samples of pulp, sludge, and effluent from this study, close to 150 (30 percent) were classified as field sample duplicates or lab duplicate splits.

The variation in TCDD/TCDF measurements among duplicate samples was evaluated since a single value representing the TCDD/TCDF concentration of each composite sample was needed to compute the TCDD/TCDF mass exports linked to the bleach lines at each pulp mill. Since the variability among duplicates was found to be relatively small, the TCDD/TCDF concentration values from duplicate analyses were averaged, first setting any non-detected values to half of the reported detection level.

4.1 CORRELATIONS BETWEEN DUPLICATE PAIRS

Figures 4-1 through 4-12 (located at the end of this section) plot the concentration values of TCDD/TCDF for all pairs of field and lab duplicate samples, subdivided by matrix into pulp, sludge, and effluent. The dashed line on each plot represents the region of perfect agreement between duplicate measurements. Non-detected samples were assigned a concentration value of half the reported detection level.

For purposes of estimating the approximate variability in each scatterplot, particularly the variability orthogonal to the dashed 45-degree line, a 95 percent confidence ellipsoid is also shown. For data that are approximately bivariate normal in distribution, only 5 percent of the data pairs would be expected to fall outside the ellipsoid (since the data are plotted on a log scale, the assumption of bivariate normality is not unreasonable given the goodness of fit results described in section 3.2). The widths of the confidence ellipsoids for lab versus field duplicates or between different export matrices roughly indicate the relative agreement between duplicate pairs in each case.

In general, both types of duplicate pairs (lab and field) show very close agreement. Few points indicate any significant discrepancy between the measured TCDD/TCDF concentration levels, although three of the plots involving lab duplicate pairs deserve special notice. In Figure 4-4, two pairs of TCDF pulp samples are more discrepant than the rest, both pairs came from the Champion International mill at Cantonment, Florida. In Figure 4-7, three pairs of TCDD sludge samples stand out; all three were collected from sulfite mills. The laboratories that conducted the analyses noted that producing reliable results was much more difficult for samples from sulfite mills than those from kraft mills.

In addition, the three sample pairs of TCDF effluent duplicates in Figure 4-12 show less agreement than the others. Two of the pairs came from the Champion International kraft mill in Houston, Texas; the other pair was collected at the Wausau sulfite mill in Brokaw, Wisconsin.

The relative agreement between lab duplicates is of particular interest, since repeated laboratory measurements on the same samples provide an estimate of the variability in concentration levels due to analytical measurement error. Though the variability in field duplicates necessarily contains components due to field sampling protocol and to analytical measurement difference, very few samples were labeled as both field duplicates <u>and</u> lab splits, so the variability of lab duplicates in this study cannot be assumed to be "contained" within the variability of field duplicates.

To support the visual impressions provided by the plots of duplicate pairs, Table 4-1 provides the Pearson correlation coefficients between the various types of field and lab duplicates, subdivided by matrix (pulp, sludge, and effluent) and pulping process (kraft and sulfite). The correlations were computed on the logged data to correspond with the above plots. Except for TCDD measurements computed for sulfite mill lab duplicates, this measure indicated very strong agreement between either field duplicate or lab duplicate pairs.

Figures 4-13 to 4-16 (located at the end of this section) illustrate the differences between TCDD/TCDF effluent pairs taken from kraft versus sulfite mills. While almost 90 percent of the kraft sample pairs (22 of 25) show very good agreement, at least 40 percent of the sulfite pairs (4 of 10) indicate significant discrepancy between the duplicate analyses. These findings suggest that samples collected from sulfite mills were more difficult to analyze than counterparts collected from kraft mills.

4.2 ANALYSIS OF DUPLICATE SAMPLE VARIABILITY

A formal analysis of variance (ANOVA) was also performed to determine the proportion of variability in TCDD/TCDF concentrations attributable directly to field sampling technique or analytical protocol. The objective of an ANOVA is to examine the total variation in a set of measurements and then partition the overall variability into smaller components representing different sources of error. Since the overall variation is known, the partitioning allows one to weigh each particular source of error relative to the total and hence, to rank the sources of error in degree of importance.

Although many sources of variation can be attributed to the TCDD/TCDF concentration data, components resulting from field sampling and analytical error were of primary concern. One source of variability that could not be measured was the potential difference between the two laboratories performing the analytical work. In only a couple cases were duplicate samples "split across labs" before analysis; hence, all members of a duplicate set were generally analyzed by the same lab. Consequently, variability attributed to repeated lab measurement comprises "within lab" differences only.

TABLE 4-1. PEARSON CORRELATIONS BETWEEN DUPLICATE PAIRS

Field Duplicates	N	TCDD Correlation	N	TCDF Correlation
Pulp	20	.952	21	.982
Sludge	9	.988	10	.987
Effluent	12	.985	13	.982
Kraft	11	.989	12	.982
Sulfite	1	---	1	---
Lab Duplicates				
Pulp	19	.994	16	.950
Sludge	21	.945	19	.989
Effluent	17	.967	18	.874
Kraft	12	.983	13	.886
Sulfite	5	.735	5	.897

Note: Correlations were computed between pairs of logged concentration values.

Tables 4-2 and 4-3 provide a breakdown of the components of total variation in TCDD/TCDF concentration values for field and lab duplicates within each matrix. For each matrix, the total sum of squared deviations (SS) from the overall mean was divided mathematically into two smaller sums of squares. The first sum of squares (SS1) was formed by calculating the average concentration value of each set of duplicate samples and then computing the squared deviations of the duplicate set means from the overall matrix mean. Conceptually, SS1 represents the variation due to differences between average TCDD/TCDF values of various duplicate sets.

The second sum of squares (SS2) was formed by computing the deviations of individual samples from the average concentration level within each duplicate set and then summing across all duplicate sets within the specific matrix. The second sum of squares is of particular interest since it represents an estimate of the variability due to differences between samples within duplicate sets and hence, is a measure of the analytical measurement error (Table 4-2) or field sampling error (Table 4-3) encountered during the 104 Mill Study.

It is important to realize that the two component sums of squares add up to the total variation, so that SS = SS1 + SS2. In this context, one can judge whether the percentage of the total variation due to field sampling or analytical measurement error (SS2 percent) is large compared with all other sources of variation, which are lumped together in SS1 percent.

For the cases in Tables 4-2 and 4-3, if one considers the variability resulting from "within duplicate set differences", with the exception of one case, less than six percent of the total variation can be attributed to differences in either field sampling or laboratory analysis. Consistent with the previous analyses, it can be fairly concluded that a minor portion of the variance in TCDD/TCDF concentrations is attributable to field sampling protocol or analytical measurement. Averaging the concentration values within duplicate sets to form a single value for subsequent analysis appears to be justified.

The exceptional case involves effluent lab duplicates for TCDF where 12 percent of the total variation can be attributed to differences between

TABLE 4-2. ANOVA TABLE FOR LAB DUPLICATES

Matrix	N	SS1	SS1%	SS2	SS2%
Pulp					
Log_{10}(TCDD)	32	11.528	99.5	0.055	0.5
Log_{10}(TCDF)	29	20.572	96.8	0.678	3.2
Sludge					
Log_{10}(TCDD)	31	21.083	94.2	1.300	5.8
Log_{10}(TCDF)	27	19.089	99.1	0.167	0.9
Effluent					
Log_{10}(TCDD)	25	10.001	97.5	0.256	2.5
Log_{10}(TCDF)	27	13.886	88.3	1.845	11.7

SS1= Between Duplicate Set Sum of Squares - Within each matrix, the deviations of duplicate set means from the overall matrix mean

SS2= Within Duplicate Set Sum of Squares - Deviations of individual samples from their respective duplicate set means

SS= Total Sum of Squares - Equal to SS1 + SS2

SS1% = (SS1/SS)*100

SS2% = (SS2/SS)*100

TABLE 4-3. ANOVA TABLE FOR FIELD DUPLICATES

Matrix	N	SS1	SS1%	SS2	SS2%
Pulp					
Log_{10}(TCDD)	37	9.562	97.7	0.224	2.3
Log_{10}(TCDF)	39	17.971	98.9	0.207	1.1
Sludge					
Log_{10}(TCDD)	15	5.027	99.0	0.050	1.0
Log_{10}(TCDF)	17	8.791	99.3	0.062	0.7
Effluent					
Log_{10}(TCDD)	21	5.016	99.1	0.043	0.9
Log_{10}(TCDF)	23	6.688	98.8	0.078	1.2

SS1= Between Duplicate Set Sum of Squares - Within each matrix, the deviations of duplicate set means from the overall matrix mean

SS2= Within Duplicate Set Sum of Squares - Deviations of individual samples from their respective duplicate set means

SS= Total Sum of Squares - Equal to SS1 + SS2

SS1% = (SS1/SS)*100

SS2% = (SS2/SS)*100

analytical measurements within duplicate sets. While this fraction does not appear to be unreasonably large, it is twice as high as any of the other cases, including the corresponding SS2 percentage for effluent TCDD lab samples. As was noted in Figure 4-12, this finding can be attributed to measurement differences from only 3 of 18 pairs of effluent samples; the remaining duplicates appear to be in very close agreement.

FIGURE 4-1

PULP FIELD DUPLICATES

TCDD

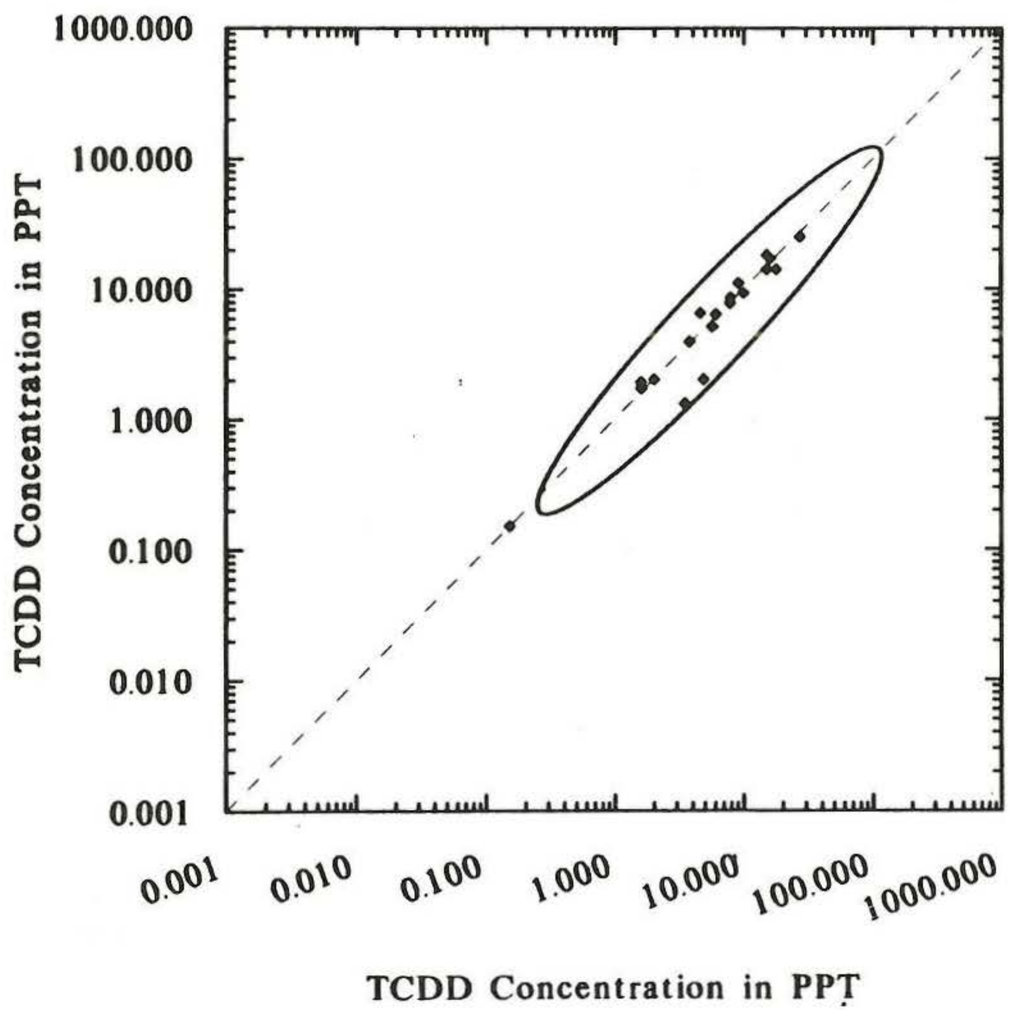


FIGURE 4-2

PULP FIELD DUPLICATES

TCDF

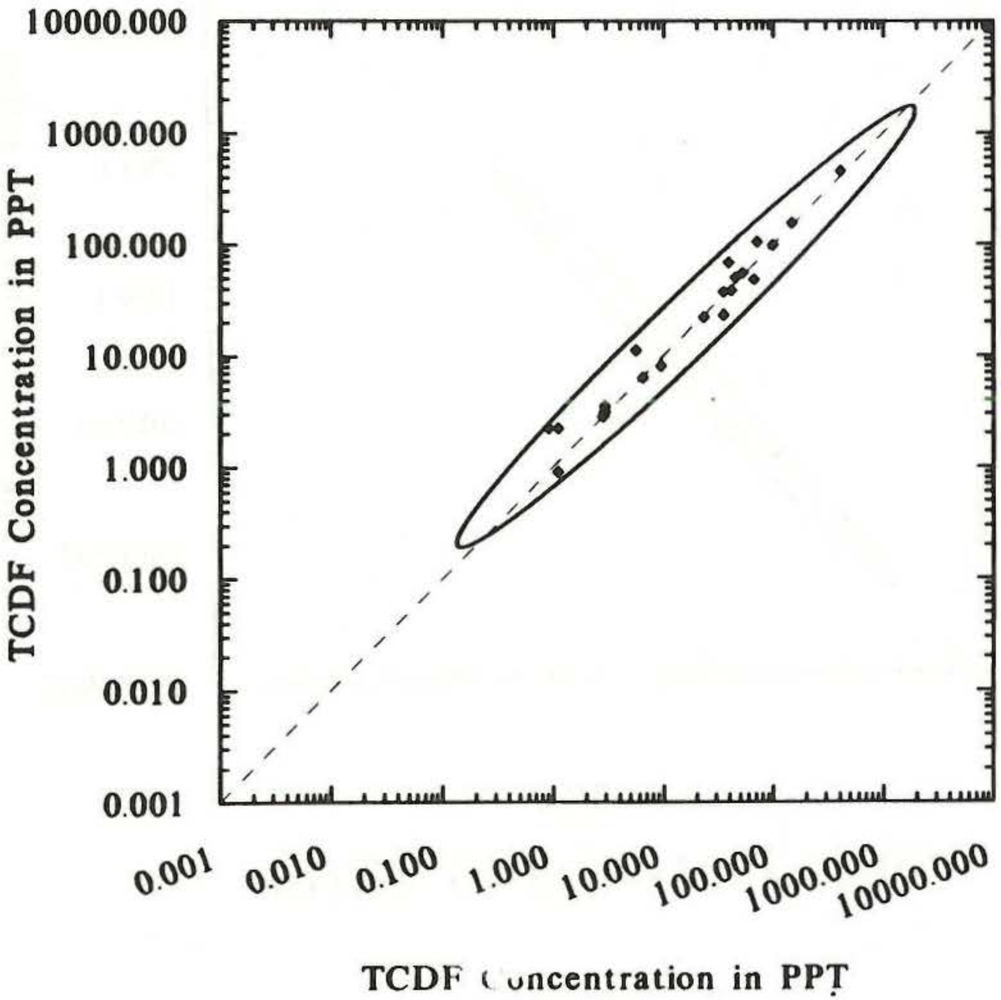


FIGURE 4-3

PULP LAB DUPLICATES

TCDD

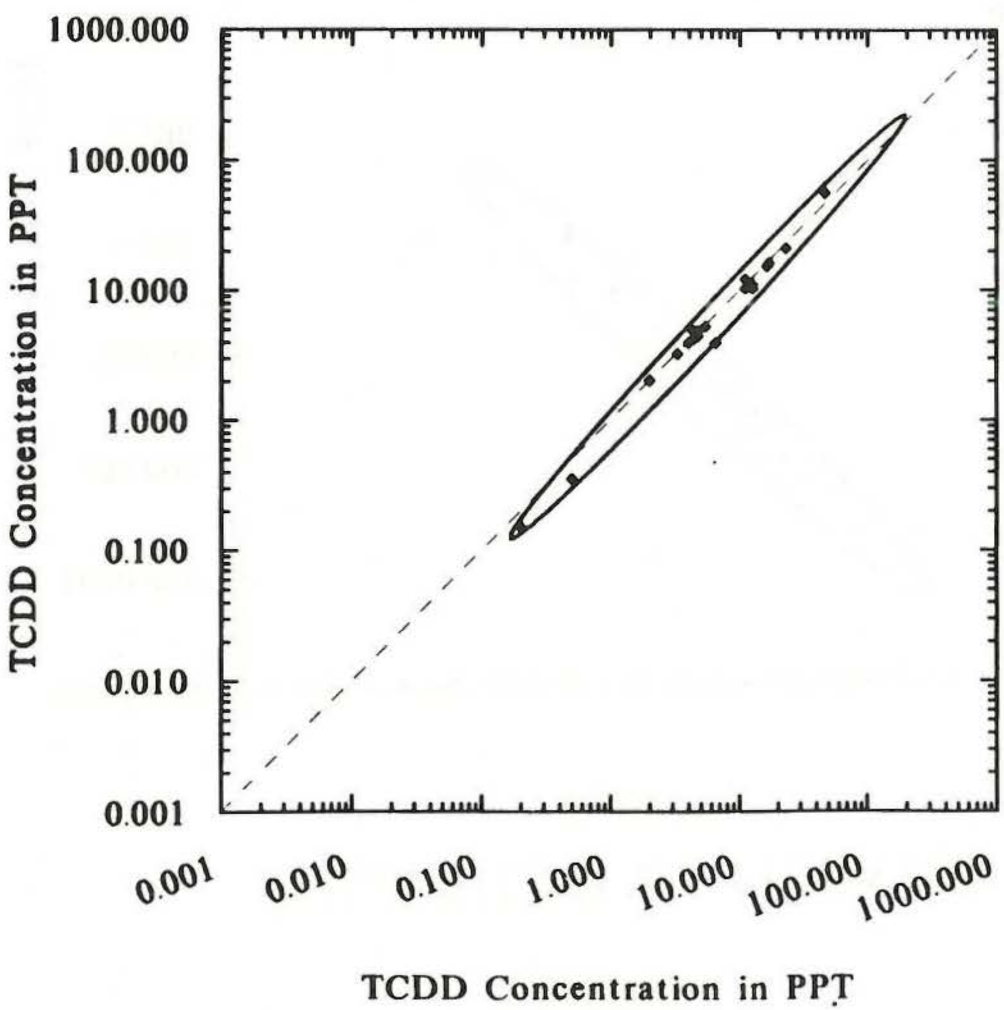


FIGURE 4-4

PULP LAB DUPLICATES

TCDF

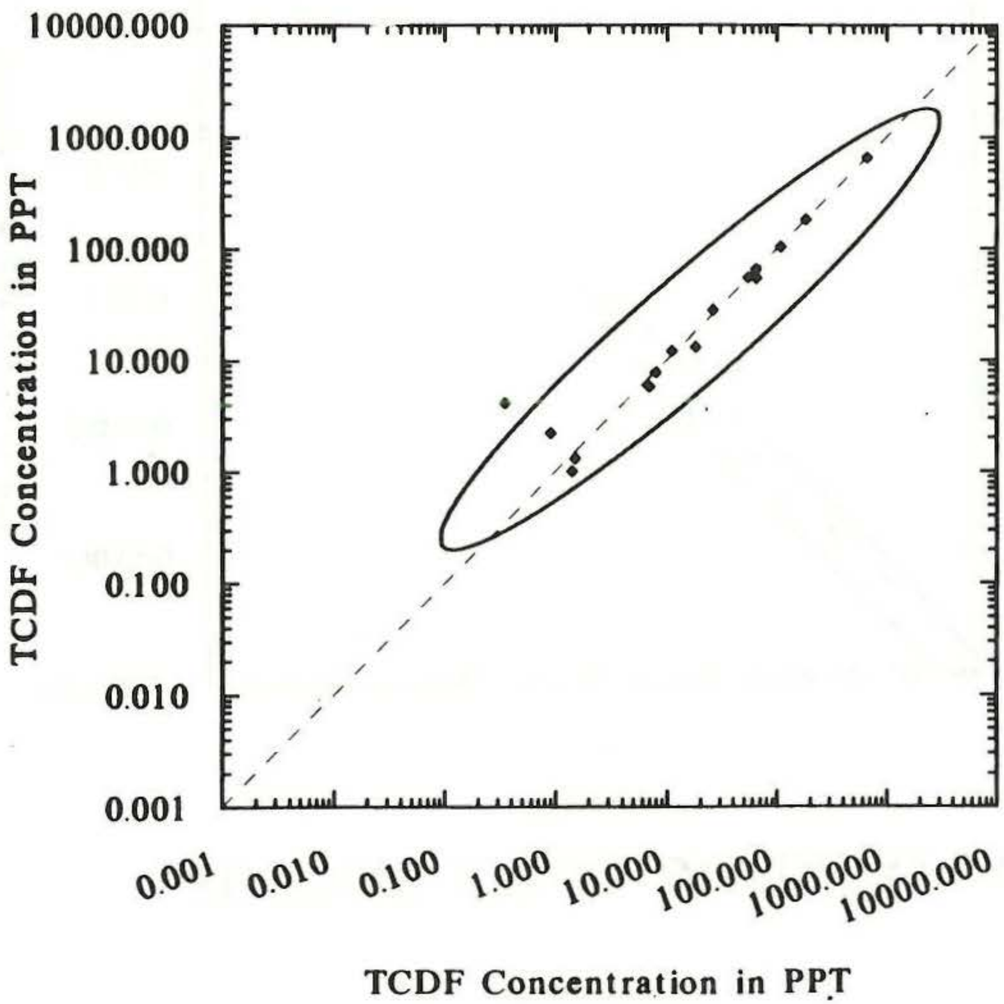


FIGURE 4-5

SLUDGE FIELD DUPLICATES

TCDD

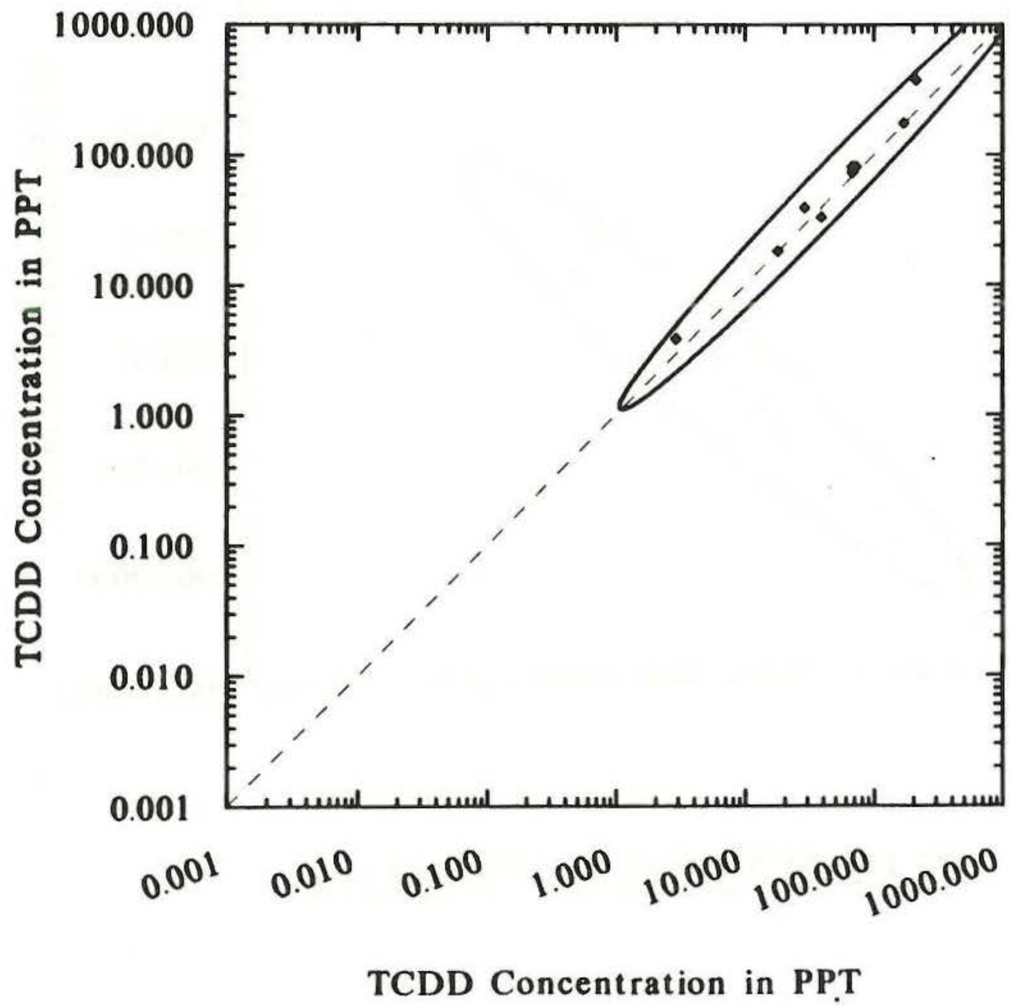


FIGURE 4-6

SLUDGE FIELD DUPLICATES

TCDF

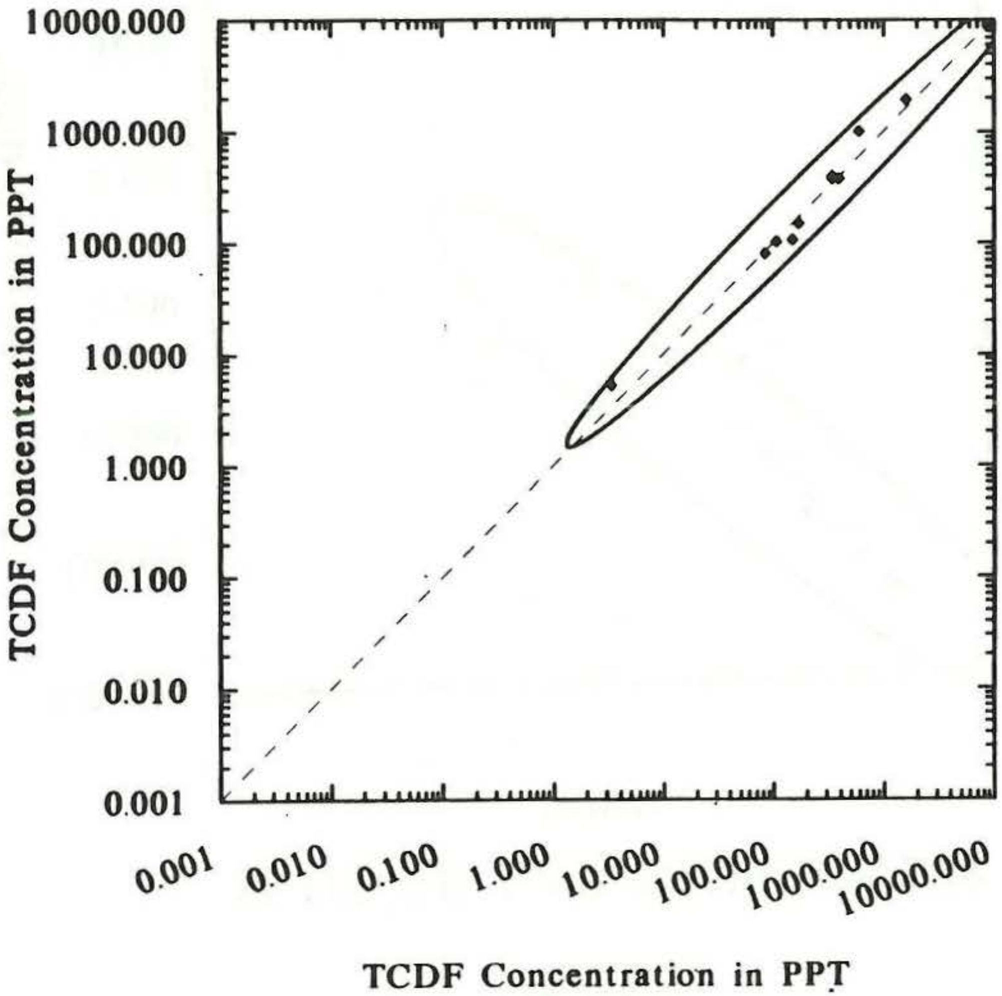


FIGURE 4-7

SLUDGE LAB DUPLICATES

TCDD

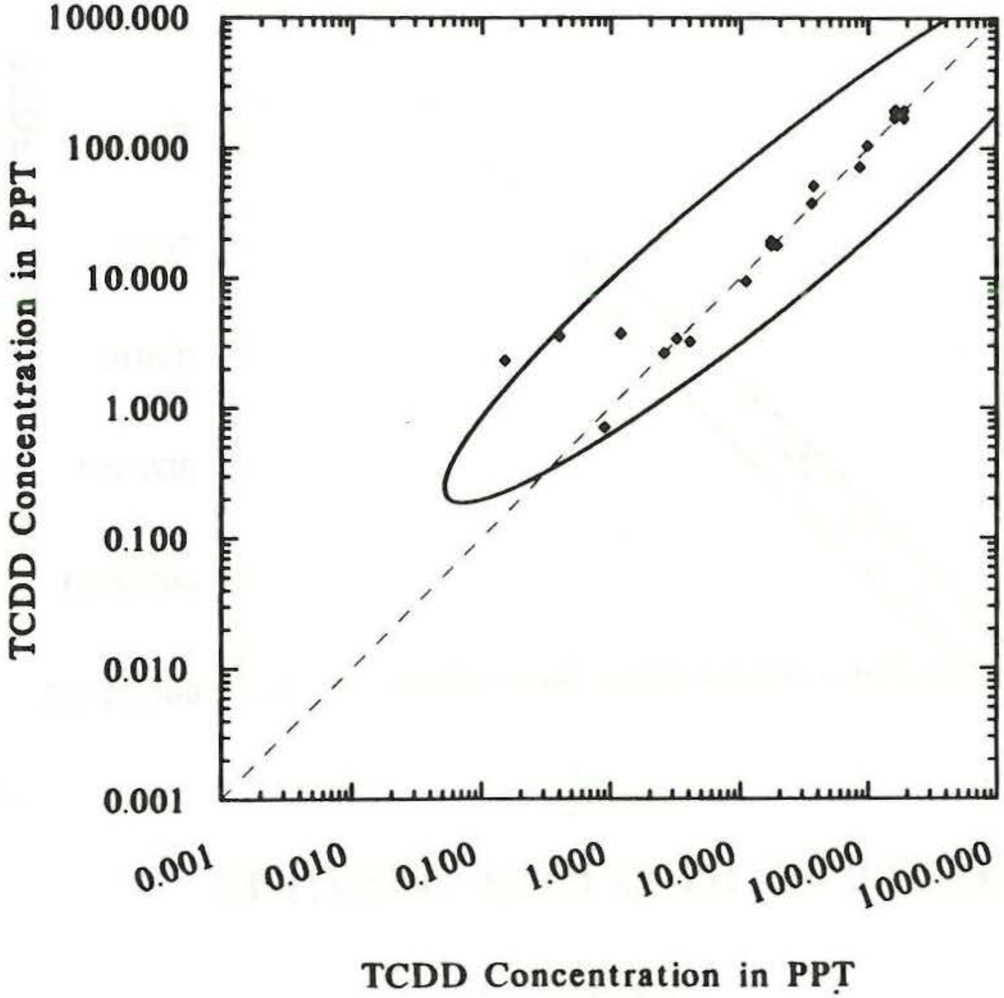


FIGURE 4-8

SLUDGE LAB DUPLICATES

TCDF

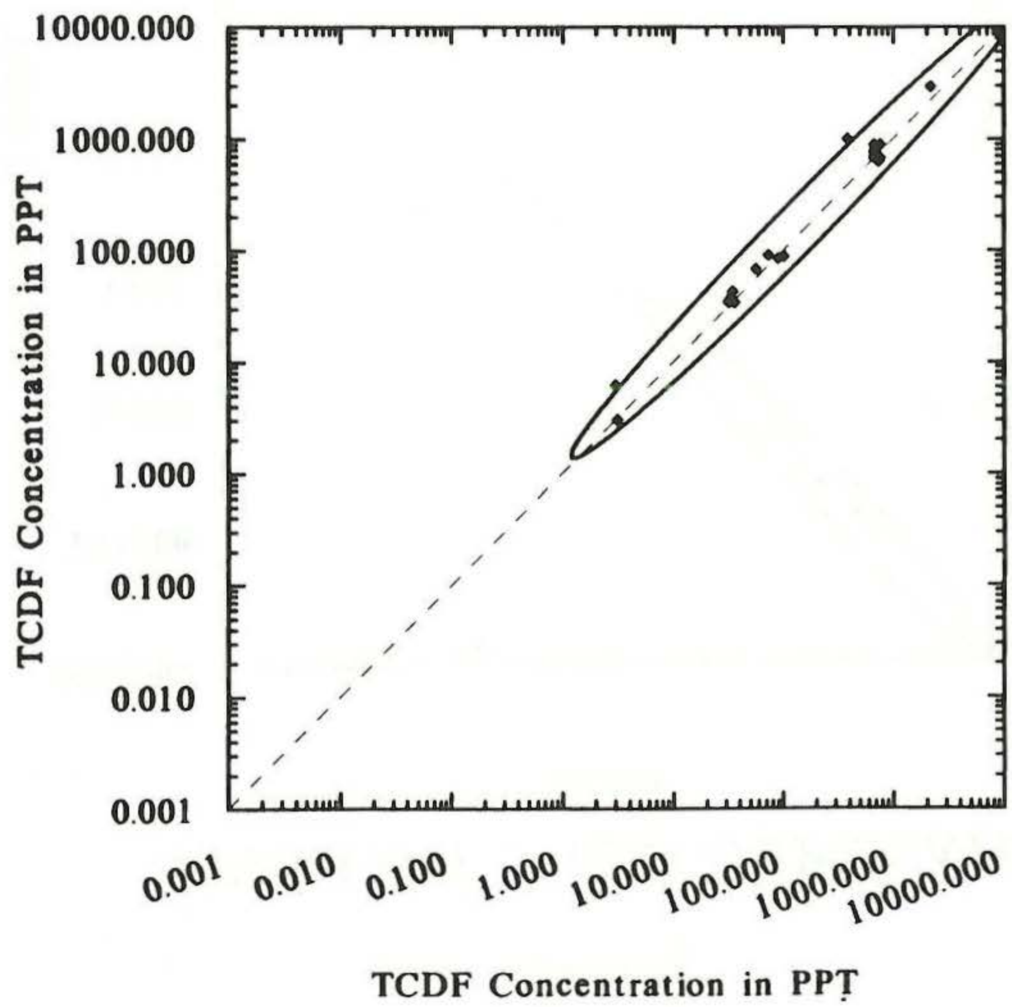


FIGURE 4-9

EFFLUENT FIELD DUPLICATES

TCDD

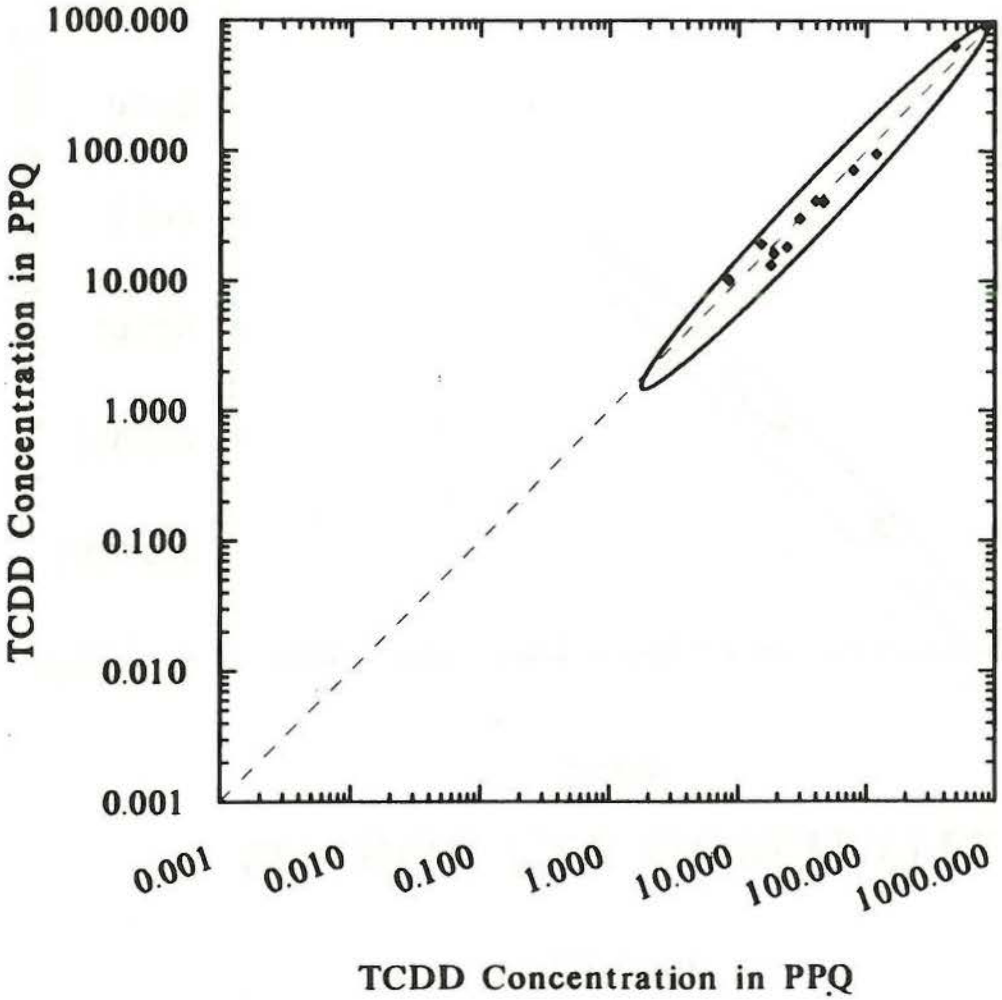


FIGURE 4-10

EFFLUENT FIELD DUPLICATES

TCDF

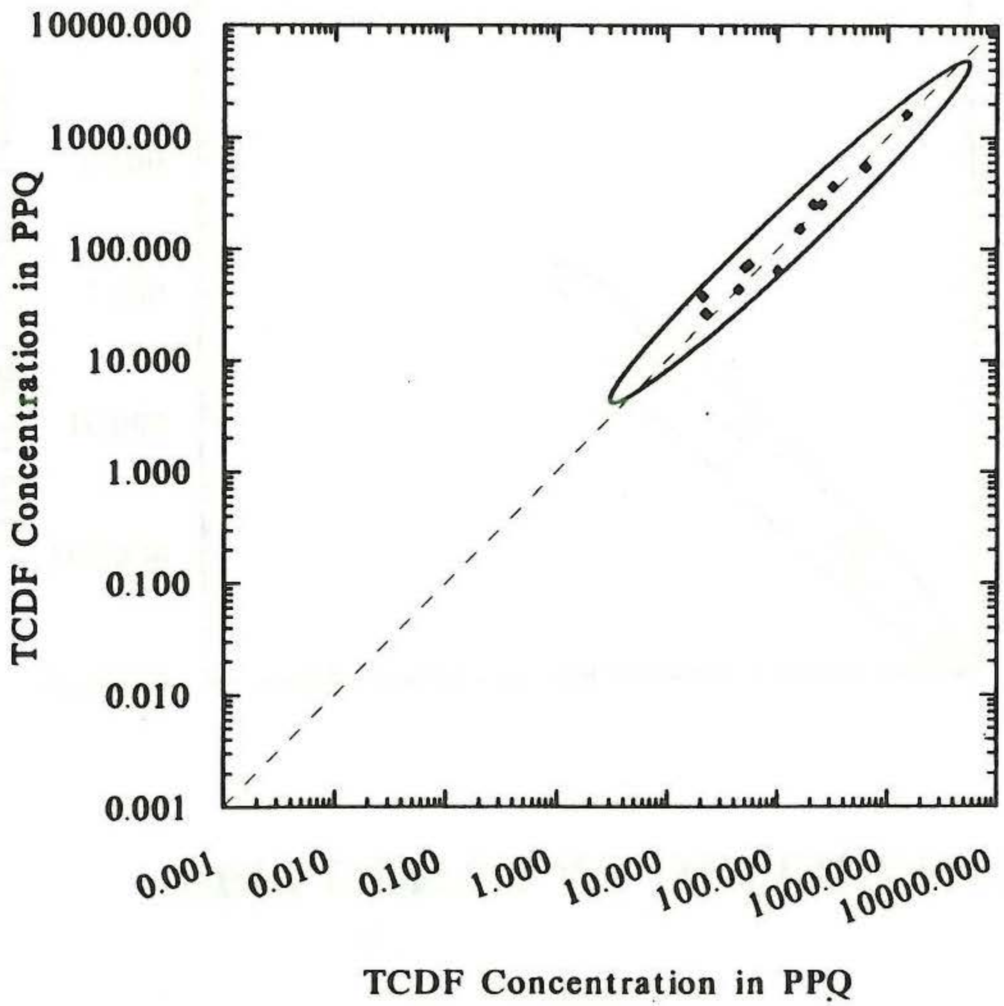


FIGURE 4-11

EFFLUENT LAB DUPLICATES

TCDD

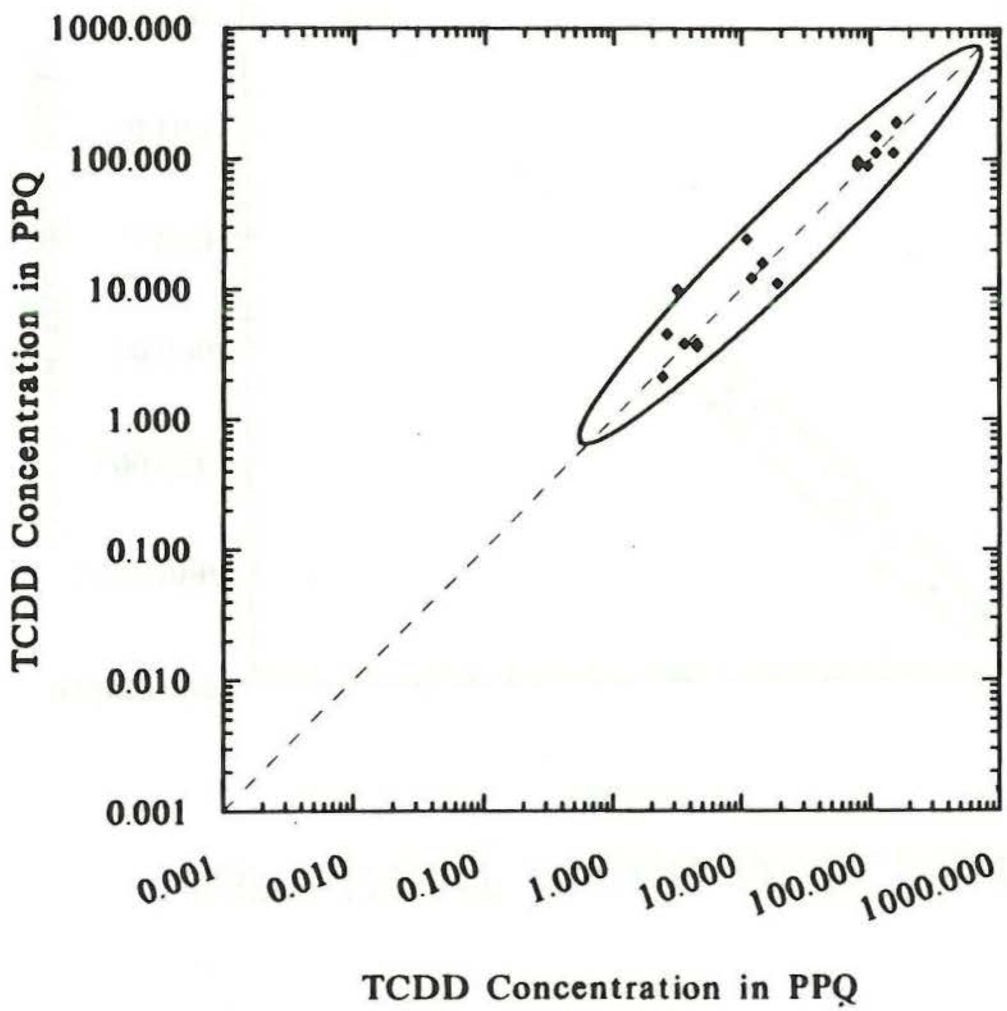


FIGURE 4-12

EFFLUENT LAB DUPLICATES

TCDF

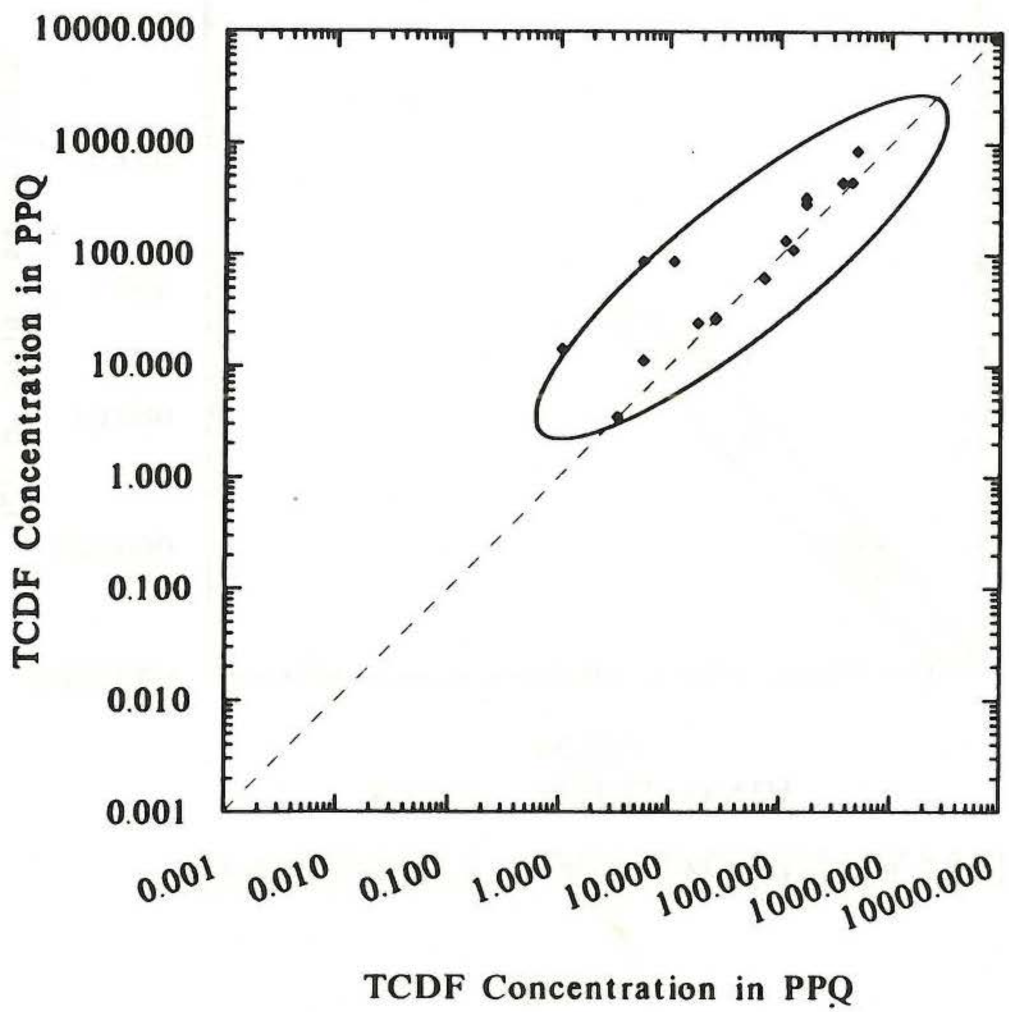


FIGURE 4-13

EFFLUENT LAB DUPLICATES

KRAFT MILLS ONLY
TCDD

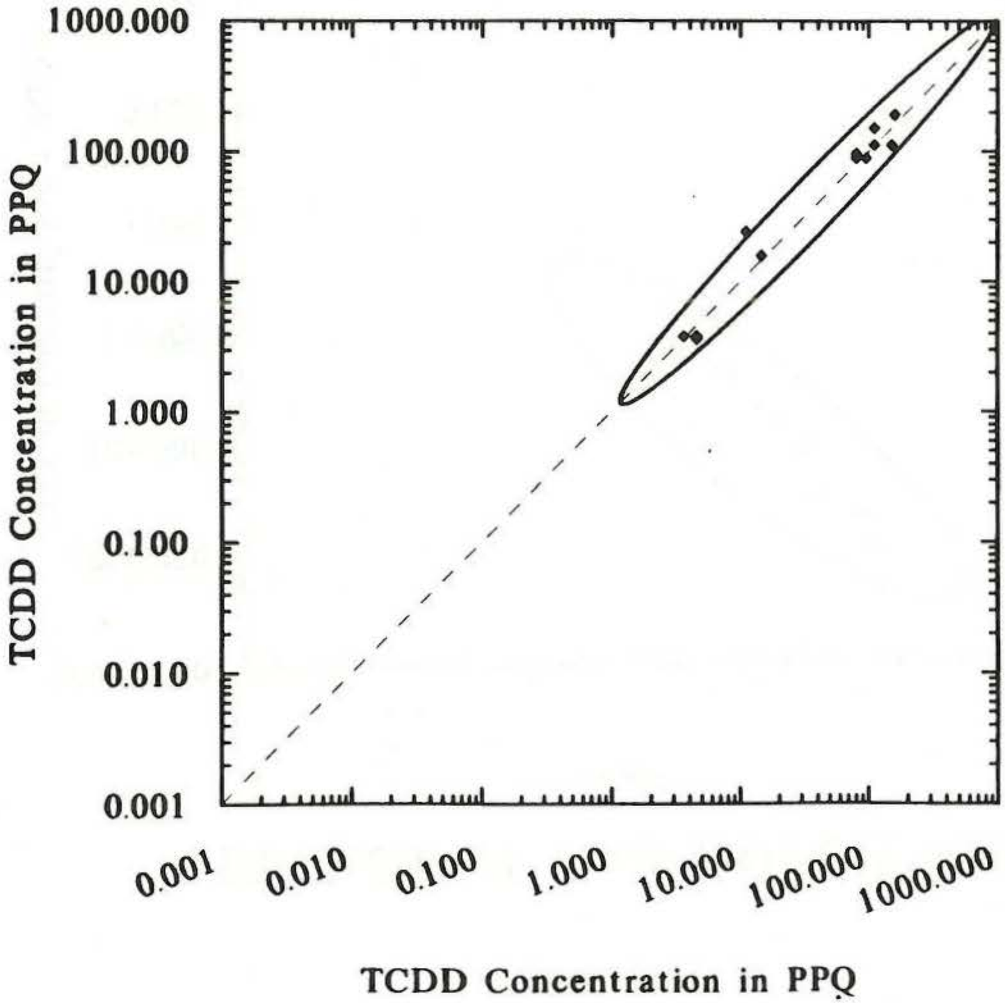


FIGURE 4-14

EFFLUENT LAB DUPLICATES

SULFITE MILLS ONLY
TCDD

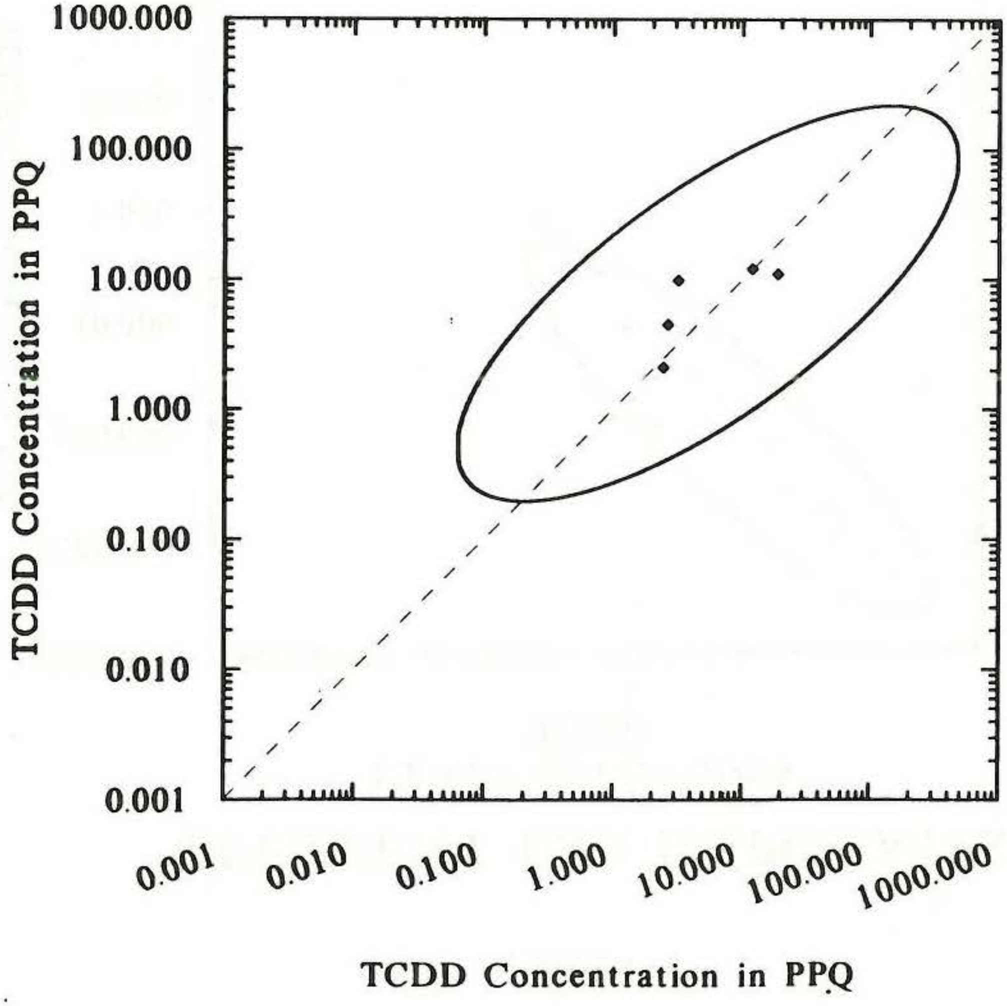


FIGURE 4-15

EFFLUENT LAB DUPLICATES

KRAFT MILLS ONLY
TCDF

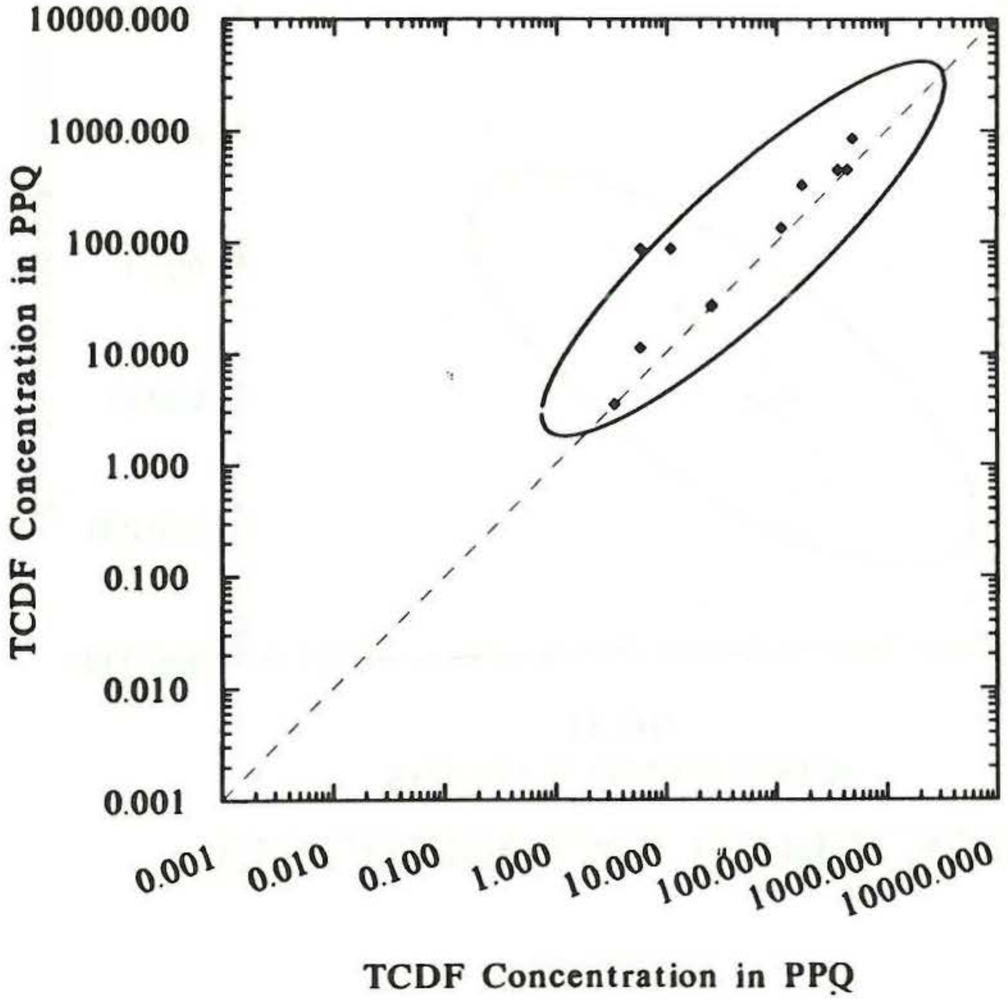
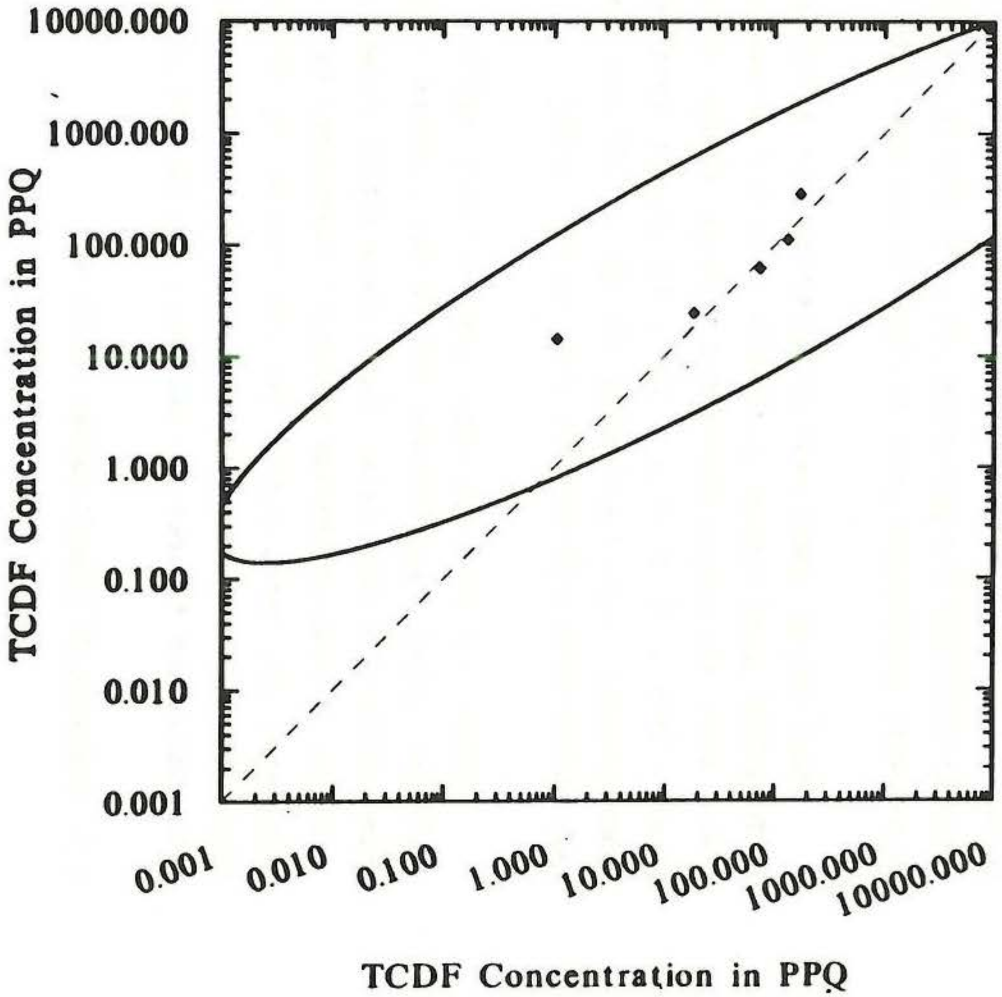


FIGURE 4-16

EFFLUENT LAB DUPLICATES

SULFITE MILLS ONLY
TCDF



5. PARTITIONING OF TCDD/TCDF MASSES INTO EXPORT MATRICES

After analyzing the duplicate lab and field samples, average 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) and 2,3,7,8-tetrachlorodibenzofuran (TCDF) concentration values were computed for each set of duplicates. These average values were then grouped with non-duplicate samples to produce a modified data set consisting of a single pulp concentration value for each bleach line and single sludge and effluent concentrations at any given mill (non-detects being set to half the reported detection level). The goal in this section was to use the modified concentration data to compute estimates of the actual mass formation rates of TCDD/TCDF for each paper mill and then to characterize how the TCDD/TCDF masses were partitioned into the exported vectors of pulp, sludge, and effluent.

Mass output rates were produced because an estimate of the total amount of TCDD/TCDF generated at each mill could not be made using concentration data alone, since the output flow rates of pulp, sludge, and effluent products varied greatly from mill to mill. The calculations involved multiplication of the concentration level of each pulp, sludge, or effluent sample by the corresponding mass output rate reported for that export vector.

Since the pulp, sludge, and effluent outflow rates were reported in different units, appropriate conversion factors were used as necessary to standardize each mass rate. Total mass export rates of TCDD/TCDF are reported in either lbs/day or lbs/ton Air-dried Brownstock Pulp (ADBSP). The latter rate represents the total output per day divided by the pulp production rate and hence, provides a mass output that is standardized for the size of the mill. (All tables and figures for section 5 are located after the text.)

5.1 VARIABILITY ACROSS EXPORT VECTORS

Tables 5-1 through 5-4 provide relevant descriptive statistics of the mass export rates for TCDD and TCDF, including the number of mills, the mean and standard deviation, the minimum and maximum, the median and upper and lower quartiles, and the 90th percentile of the mass rate distributions. For each matrix and analyte, probability plots (appendix B) indicated that the TCDD/TCDF mass distributions could be approximated as lognormal. The tables provide corresponding statistics for the percentage of the total output at each mill attributable to each export matrix (pulp, sludge, and effluent). The same statistics were also recomputed after the mills were subdivided by pulping process (kraft and sulfite) and wastewater treatment (Activated Sludge Wastewater Treatment [ACT] and Aerated Stabilization Basins [ASB]).

One of the most apparent findings of these tables is the tremendous variability exhibited from mill to mill within each matrix. Figures 5-1 through 5-4 provide boxplots illustrating the range of variability from different perspectives. The first two figures represent the percentage of total TCDD/TCDF output partitioned to each matrix. Each boxplot was constructed so that the top and bottom edges of the box represent the lower and upper quartiles of the distribution of percentages taken across all mills, while the line dividing the box in two is the median. The two "whiskers" extending from the edges of the box mark a range covering the middle 95 percent of all the data points.

Figures 5-3 and 5-4 represent the distributions of TCDD/TCDF mass formation adjusted for the pulp production rate at each mill (lbs/ton ADBSP). In either case, it is clear that some mills partition much more of their TCDD/TCDF mass to one matrix than the others and that the pattern is not consistent from mill to mill.

5.2 KRAFT VERSUS SULFITE MILLS

To test the significance of the differences between kraft and sulfite mills suggested in Tables 5-1 and 5-3, two-sample t-tests were run on the logged observations of TCDD/TCDF exports: one set for the unadjusted mass rates (lbs/day) and one for the mass rates adjusted by the mill-specific pulp production rate (lbs/ton ADBSP). The results are summarized in Table 5-5.

Since the TCDD/TCDF mass export rates followed approximate lognormal distributions, comparison of these variables was made on the log scale in order to make inferences concerning the t-test as valid as possible. Such inferences are generally valid when the tested data have been sampled from a normal distribution, but not necessarily in other cases. An important consequence of using the logged data is that comparing arithmetic means on the log scale is equivalent to comparing the geometric means of the mass export rates on the original scale. When data follow an exact lognormal distribution the geometric mean is equivalent to the median. Therefore, the comparison presented here is approximately one between the medians of the original data, which have been listed beside the corresponding means of the logged data in Table 5-5. For highly skewed data, such as that encountered in the 104 Mill Study, medians actually provide a better impression of the bulk of the sample since the effect of outlying points on the median is minimal.

Several points should be kept in mind when interpreting the results of these significance tests. T-tests are designed to indicate how likely it is that an observed mean difference between two groups of sample data reflects an actual difference between the overall means of the populations from which the samples were taken. The p-value is one measure of this likelihood and represents the probability that if the study were repeated from scratch and a new set of measurements procured, one would observe a difference between the samples at least as great as the difference already observed, assuming that no real difference was expected. Low p-values suggest that real differences between the two groups probably exist (i.e., that the observed differences are statistically significant).

When comparing the mass rates that are unadjusted for mill-specific pulp production rates (lbs/day), the p-values of Table 5-5 indicate that significantly more TCDD/TCDF was exported at kraft mills than sulfite mills when considered on a total basis and for each export matrix separately.

When the adjusted mass rates (lbs/ton ADBSP) were compared, the results changed only slightly: significantly more TCDD/TCDF mass was exported at kraft mills than sulfite mills for pulp and effluent vectors and for all exports combined. However, the difference between kraft and sulfite mills with respect to TCDD/TCDF in sludge was not found to be statistically significant.

Nevertheless, in the sample data, kraft mills tended to export more sludge-based TCDD/TCDF on average than their sulfite counterparts.

5.3 ACT VERSUS ASB WASTEWATER TREATMENTS

To interpret the main findings of Tables 5-2 and 5-4 with regard to wastewater treatment differences, Figures 5-5 through 5-8 provide boxplots of the TCDD/TCDF output rates showing the percentage of total output attributable to sludge or effluent vectors, classified by wastewater treatment type.

The boxplots illustrate that the percentages of total TCDD/TCDF output to sludge and effluent vectors were highly variable from mill to mill; however, there was a consistent tendency for the median percentage of TCDD/TCDF outflow to sludge to be much higher for ACT than ASB, and the corresponding percentage of outflow to effluent to be lower. The same differences between treatment types were exhibited by kraft mills considered separately; among sulfite mills, only one with usable data employed ASB-type waste treatment, so a similar comparison was not feasible.

In part, the pattern exhibited in Figures 5-5 through 5-8 with kraft and sulfite mills combined is probably attributable to the limitations of the data. Sludge samples taken from ACT treatment systems consisted of both primary and secondary sludges, while those collected from ASB facilities only comprised primary sludge. Had representative secondary sludges from ASB-type treatment systems been obtainable, the estimated sludge-based TCDD/TCDF mass exports for ASB mills would have probably been higher than observed. Since the overall TCDD/TCDF mass rates would also be higher, this would have simultaneously raised the percent of total TCDD/TCDF output typically attributable to sludge and lowered the percent of total TCDD/TCDF output attributable to effluent, making the observed differences between ACT and ASB treatments less dramatic.

Figures 5-9 through 5-12 provide boxplots of the effluent and sludge TCDD/TCDF mass export rates (in lbs/ton ADBSP) on a logarithmic scale, subdivided by type of waste treatment. When considered on a mass rate basis instead of a percentage of total output, sludge-based TCDD/TCDF again appears to be significantly higher on average at ACT mills than ASB mills. How much of this difference is due to the different nature of the sampled ACT sludges versus ASB sludges can not be estimated.

Sampled effluents from the 104 Mill Study should be more directly comparable, and in this case, the export rates of effluent-based TCDD/TCDF tended to be somewhat higher at ASB mills than ACT mills, though not in every comparison. Median effluent TCDD exports were slightly higher for ASB mills than ACT mills, but the reverse was true for effluent TCDF exports. In both cases, however, the lower and upper quartiles were larger for the set of ASB mills, suggesting that the middle 50 percent of ASB mills tended to export more effluent TCDD/TCDF than the middle 50 percent of ACT mills.

T-tests calculated on the logged TCDD/TCDF mass export rates partially confirmed the visual impressions of Figures 5-9 to 5-12 (Table 5-6). Considered on the basis of production-adjusted mass export rates (lbs/ton ADBSP), no significant differences at the 5 percent level were found between the median effluent export rates of ACT versus ASB mills. However, mills with ACT-type waste treatment exported significantly more TCDD/TCDF in sludge vectors than mills with ASB-type treatment. The same results were echoed by kraft mills considered separately. It should also be noted that the results were somewhat different when considering unadjusted TCDD/TCDF mass output rates (lbs/day). In that case, significantly more effluent TCDD was exported by ASB-type waste treatments than ACT-type treatments; the same was not true for effluent TCDF or for kraft mills considered separately.

5.4 OVERALL PARTITIONING OF TCDD/TCDF

Pie charts representing the overall partitioning of TCDD/TCDF into pulp, sludge, and effluent are presented in Figures 5-13 to 5-16. To construct each pie chart, total TCDD/TCDF mass exports (lbs/day) were summed across all mills for each matrix, and the percentage of the total exported to pulp, sludge, or effluent is shown on the chart. Similar pie charts were also constructed for kraft and sulfite mills considered separately. These pie charts indicate the estimated total daily outputs of TCDD/TCDF poundage for all U.S. bleached pulp mills that had usable data.

To accompany the pie charts, Tables 5-7 and 5-8 present the total mass outputs of TCDD/TCDF summed across all kraft or sulfite mills, the corresponding average output per mill, and the percentage of the total summed output exported to pulp, sludge, or effluent vectors. The two tables differ in that the first provides total outputs without adjustment for the pulp production rate at each mill, while the second sums the output of each mill after dividing first by the pulp production rate, to normalize for mill size.

TCDD/TCDF outputs for kraft mills were considerably larger on any basis than the outputs for sulfite mills. However, kraft and sulfite mills exhibited similar patterns of the percentages of total output partitioned to different matrices. With one exception (TCDD output at sulfite mills), the largest fraction of TCDD/TCDF mass output was partitioned to pulp, being more than 50 percent for TCDF exports from sulfite mills.

Considering the total estimated mass outputs of TCDD/TCDF for all matrices combined, these data suggest combined production totals of close to 0.004 lbs/day of TCDD and 0.032 lbs/day of TCDF at U.S. bleached pulp mills. Estimates of the per mill averages were close to 0.00005 lbs/day for TCDD and 0.00048 lbs/day for TCDF; however, substantial variation in the TCDD/TCDF mass exports was exhibited from mill to mill.

TABLE 5-1. DESCRIPTIVE STATISTICS FOR TCDD

TCDD Exports	N	Mean	Std	Minimum	Maximum	Lower Quartile	Median	Upper Quartile	90th Percentile
All Samples									
TCDD in Pulp (lbs/day)*10^6	101	15.75	22.08	0.072	140.80	1.36	8.86	19.20	45.02
TCDD in Sludge (lbs/day)*10^6	99	13.38	34.54	0.000	240.30	0.45	8.86	7.01	34.05
TCDD in Effluent (lbs/day)*10^6	97	12.07	20.93	0.094	123.40	0.99	4.30	14.13	30.11
Total TCDD (lbs/day)*10^6	95	42.18	61.33	0.507	374.00	5.92	18.60	49.47	115.24
TCDD in Pulp (lbs/ton ADBSP)*10^8	101	1.71	2.27	0.010	13.31	0.30	0.98	2.26	4.38
TCDD in Sludge (lbs/ton ADBSP)*10^8	99	1.28	2.60	0.000	15.90	0.05	0.25	1.30	3.88
TCDD in Effluent (lbs/ton ADBSP)*10^8	97	1.22	1.90	0.011	10.88	0.17	0.57	1.30	2.79
Total TCDD (lbs/ton ADBSP)*10^8	95	4.31	5.31	0.066	30.56	0.96	2.13	5.95	11.02
% TCDD OUTPUT to Pulp	95	39.92	22.48	2.835	91.08	21.98	40.19	59.03	70.08
% TCDD OUTPUT to Sludge	95	25.79	24.39	0.000	85.79	4.31	16.67	45.18	62.60
% TCDD OUTPUT to Effluent	95	34.30	23.47	1.536	86.53	14.63	32.10	49.30	72.35
Kraft Samples									
TCDD in Pulp (lbs/day)*10^6	84	18.33	23.25	0.084	140.80	3.20	10.85	23.35	48.58
TCDD in Sludge (lbs/day)*10^6	83	15.48	37.34	0.000	240.30	0.46	10.85	7.73	50.49
TCDD in Effluent (lbs/day)*10^6	81	14.09	22.35	0.161	123.40	1.43	5.82	18.04	31.51
Total TCDD (lbs/day)*10^6	80	48.84	64.55	0.692	374.00	11.43	24.37	68.21	136.78
TCDD in Pulp (lbs/ton ADBSP)*10^8	84	1.95	2.39	0.010	13.31	0.50	1.16	2.38	4.55
TCDD in Sludge (lbs/ton ADBSP)*10^8	83	1.44	2.80	0.000	15.90	0.05	0.25	1.46	4.29
TCDD in Effluent (lbs/ton ADBSP)*10^8	81	1.38	2.03	0.011	10.88	0.23	0.61	1.70	3.01
Total TCDD (lbs/ton ADBSP)*10^8	80	4.86	5.57	0.066	30.56	1.21	2.80	6.53	12.14
% TCDD OUTPUT to Pulp	80	43.05	20.55	4.046	88.40	24.78	41.90	60.59	70.29
% TCDD OUTPUT to Sludge	80	23.91	24.34	0.000	85.79	3.51	15.79	43.50	60.62
% TCDD OUTPUT to Effluent	80	33.05	22.71	1.536	86.08	14.66	26.84	46.45	69.20
Sulfite Samples									
TCDD in Pulp (lbs/day)*10^6	15	0.93	1.43	0.072	4.93	0.13	0.20	1.22	4.04
TCDD in Sludge (lbs/day)*10^6	14	1.54	2.31	0.026	8.22	0.26	0.20	1.54	6.63
TCDD in Effluent (lbs/day)*10^6	15	1.31	1.33	0.094	4.30	0.24	0.85	1.78	4.19
Total TCDD (lbs/day)*10^6	14	3.80	3.61	0.507	12.70	1.34	2.43	5.59	11.01
TCDD in Pulp (lbs/ton ADBSP)*10^8	15	0.35	0.77	0.020	3.00	0.03	0.06	0.40	1.73
TCDD in Sludge (lbs/ton ADBSP)*10^8	14	0.37	0.44	0.008	1.37	0.04	0.16	0.69	1.24
TCDD in Effluent (lbs/ton ADBSP)*10^8	15	0.33	0.37	0.031	1.28	0.11	0.15	0.42	1.11
Total TCDD (lbs/ton ADBSP)*10^8	14	1.03	1.19	0.206	4.53	0.27	0.46	1.55	3.32
% TCDD OUTPUT to Pulp	14	21.99	26.13	2.835	91.08	6.20	10.48	26.87	78.65
% TCDD OUTPUT to Sludge	14	35.70	23.72	1.935	77.20	12.23	38.77	55.80	70.98
% TCDD OUTPUT to Effluent	14	42.32	27.57	6.981	86.53	12.37	39.54	65.30	86.21

TABLE 5-2. DESCRIPTIVE STATISTICS FOR TCDD (BY WASTEWATER TREATMENT)

WASTEWATER TREATMENT=ACT

TCDD Exports	N	Mean	Std	Minimum	Maximum	Lower Quartile	Median	Upper Quartile	90^{th} Percentile
TCDD in Pulp (lbs/day)*10^6	41	16.16	25.61	0.072	140.80	1.21	7.28	19.34	47.88
TCDD in Sludge (lbs/day)*10^6	39	13.17	21.06	0.026	85.59	1.33	7.28	14.31	50.45
TCDD in Effluent (lbs/day)*10^6	40	7.46	10.55	0.094	39.50	0.71	2.88	9.26	29.66
Total TCDD (lbs/day)*10^6	39	37.19	48.53	0.507	201.40	4.97	18.51	46.49	124.00
TCDD in Pulp (lbs/ton ADBSP)*10^8	41	1.97	2.47	0.030	13.31	0.27	1.46	2.64	4.51
TCDD in Sludge (lbs/ton ADBSP)*10^8	39	1.46	1.71	0.008	6.88	0.20	0.63	2.22	4.40
TCDD in Effluent (lbs/ton ADBSP)*10^8	40	0.91	1.12	0.031	5.17	0.14	0.52	1.24	2.79
Total TCDD (lbs/ton ADBSP)*10^8	39	4.38	4.32	0.206	19.04	1.08	2.77	6.47	12.02
% TCDD OUTPUT to Pulp	39	39.55	23.57	2.835	91.08	20.71	36.42	62.43	69.91
% TCDD OUTPUT to Sludge	39	34.45	21.76	0.809	77.31	16.22	34.26	53.57	64.76
% TCDD OUTPUT to Effluent	39	26.00	21.13	1.969	86.53	12.76	20.02	35.40	58.06

WASTEWATER TREATMENT=ASB

TCDD Exports	N	Mean	Std	Minimum	Maximum	Lower Quartile	Median	Upper Quartile	90^{th} Percentile
TCDD in Pulp (lbs/day)*10^6	47	17.21	20.41	0.128	102.40	2.57	11.41	23.85	46.12
TCDD in Sludge (lbs/day)*10^6	48	16.45	45.59	0.000	240.30	0.45	11.41	6.61	52.24
TCDD in Effluent (lbs/day)*10^6	44	18.55	28.06	0.161	123.40	1.40	9.39	25.07	47.20
Total TCDD (lbs/day)*10^6	44	53.63	75.31	0.902	374.00	10.14	28.70	65.66	150.80
TCDD in Pulp (lbs/ton ADBSP)*10^8	47	1.63	2.22	0.020	11.20	0.46	0.88	2.01	3.45
TCDD in Sludge (lbs/ton ADBSP)*10^8	48	1.40	3.36	0.000	15.90	0.05	0.18	0.77	4.19
TCDD in Effluent (lbs/ton ADBSP)*10^8	44	1.66	2.53	0.011	10.88	0.19	0.67	1.81	6.17
Total TCDD (lbs/ton ADBSP)*10^8	44	4.83	6.46	0.066	30.56	1.01	2.07	5.84	14.25
% TCDD OUTPUT to Pulp	44	40.57	21.35	4.046	88.40	24.78	40.95	55.97	71.75
% TCDD OUTPUT to Sludge	44	21.41	25.65	0.000	85.79	2.70	7.82	34.62	69.23
% TCDD OUTPUT to Effluent	44	38.02	22.96	1.536	86.08	23.65	35.28	56.01	72.65

TABLE 5-3. DESCRIPTIVE STATISTICS FOR TCDF

TCDF Exports	N	Mean	Std	Minimum	Maximum	Lower Quartile	Median	Upper Quartile	90^{th} Percentile
All Samples									
TCDF in Pulp (lbs/day)*10^6	102	147.80	339.14	0.053	2523.00	5.26	31.63	127.62	356.47
TCDF in Sludge (lbs/day)*10^6	102	82.92	273.27	0.000	2394.00	1.73	31.63	41.93	189.82
TCDF in Effluent (lbs/day)*10^6	99	94.14	229.62	0.054	1542.00	4.33	15.35	71.96	273.40
Total TCDF (lbs/day)*10^6	96	334.30	711.90	0.743	4511.00	22.50	74.64	328.92	735.14
TCDF in Pulp (lbs/ton ADBSP)*10^9	102	20.96	62.53	0.010	524.01	0.93	3.94	13.89	45.58
TCDF in Sludge (lbs/ton ADBSP)*10^9	102	8.75	23.77	0.000	195.59	0.17	1.36	5.26	23.30
TCDF in Effluent (lbs/ton ADBSP)*10^9	99	12.67	41.60	0.018	365.71	0.64	2.08	7.22	29.99
Total TCDF (lbs/ton ADBSP)*10^9	96	43.29	116.62	0.147	953.88	3.46	8.62	30.42	120.54
% TCDF Output to Pulp	96	43.96	23.37	0.590	92.18	23.33	45.23	61.64	76.84
% TCDF Output to Sludge	96	25.83	24.98	0.000	93.81	3.94	18.98	44.90	62.02
% TCDF Output to Effluent	96	30.22	22.19	0.323	86.84	11.04	26.23	44.47	64.62
Kraft Samples									
TCDF in Pulp (lbs/day)*10^6	85	162.67	363.34	0.459	2523.00	10.93	35.75	132.20	399.20
TCDF in Sludge (lbs/day)*10^6	85	94.41	297.17	0.000	2394.00	1.59	35.75	57.59	203.36
TCDF in Effluent (lbs/day)*10^6	82	106.85	248.81	0.417	1542.00	5.07	21.96	77.66	282.64
Total TCDF (lbs/day)*10^6	80	374.93	764.28	2.128	4511.00	29.30	98.79	370.95	795.62
TCDF in Pulp (lbs/ton ADBSP)*10^9	85	22.67	67.53	0.090	524.01	1.65	4.30	14.09	44.17
TCDF in Sludge (lbs/ton ADBSP)*10^9	85	9.67	25.72	0.000	195.59	0.12	1.32	6.26	28.32
TCDF in Effluent (lbs/ton ADBSP)*10^9	82	14.37	45.38	0.048	365.71	0.78	2.51	8.11	30.39
Total TCDF (lbs/ton ADBSP)*10^9	80	48.33	126.16	0.147	953.88	4.66	10.45	33.19	122.87
% TCDF Output to Pulp	80	46.67	21.34	4.383	92.18	26.04	45.49	64.27	77.09
% TCDF Output to Sludge	80	23.32	23.46	0.000	91.35	3.76	15.59	43.01	60.36
% TCDF Output to Effluent	80	30.02	21.41	0.323	86.84	11.22	26.99	44.47	64.26
Sulfite Samples									
TCDF in Pulp (lbs/day)*10^6	15	52.08	159.47	0.053	615.70	0.18	2.03	8.54	325.42
TCDF in Sludge (lbs/day)*10^6	15	14.26	39.09	0.000	154.90	1.77	2.03	7.46	69.09
TCDF in Effluent (lbs/day)*10^6	15	26.17	70.82	0.054	273.40	0.59	1.61	8.18	153.42
Total TCDF (lbs/day)*10^6	14	89.12	275.66	0.743	1044.00	4.31	9.19	22.29	564.41
TCDF in Pulp (lbs/ton ADBSP)*10^9	15	10.79	26.49	0.010	85.80	0.05	0.42	1.98	73.08
TCDF in Sludge (lbs/ton ADBSP)*10^9	15	2.71	5.41	0.000	21.59	0.18	1.40	2.87	11.56
TCDF in Effluent (lbs/ton ADBSP)*10^9	15	3.96	9.67	0.018	38.10	0.19	0.73	4.00	19.57
Total TCDF (lbs/ton ADBSP)*10^9	14	13.81	38.04	0.243	145.48	0.94	3.47	8.45	78.03
% TCDF Output to Pulp	14	26.47	28.18	0.590	90.70	6.47	12.10	53.80	74.87
% TCDF Output to Sludge	14	40.83	29.73	2.002	93.81	13.81	39.25	62.01	88.62
% TCDF Output to Effluent	14	32.70	28.08	3.624	86.56	8.08	25.28	54.09	81.92

TABLE 5-4. DESCRIPTIVE STATISTICS FOR TCDF (BY WASTEWATER TREATMENT)

WASTEWATER TREATMENT=ACT

TCDF Exports	N	Mean	Std	Minimum	Maximum	Lower Quartile	Median	Upper Quartile	90^{th} Percentile
TCDF in Pulp (lbs/day)*10^6	41	111.81	186.86	0.053	964.40	5.01	28.45	129.05	300.96
TCDF in Sludge (lbs/day)*10^6	41	72.40	147.58	0.000	846.00	4.72	28.45	91.09	205.84
TCDF in Effluent (lbs/day)*10^6	41	49.60	86.40	0.054	422.00	1.83	12.00	67.90	142.08
Total TCDF (lbs/day)*10^6	39	233.07	348.74	0.743	1484.00	20.64	79.23	361.80	678.70
TCDF in Pulp (lbs/ton ADBSP)*10^9	41	17.75	34.61	0.010	193.81	1.06	4.34	20.23	56.59
TCDF in Sludge (lbs/ton ADBSP)*10^9	41	8.93	15.03	0.000	68.05	1.27	2.87	9.09	28.43
TCDF in Effluent (lbs/ton ADBSP)*10^9	41	7.62	16.36	0.018	90.95	0.43	2.08	6.45	27.03
Total TCDF (lbs/ton ADBSP)*10^9	39	33.33	57.24	0.243	299.61	3.76	11.13	27.85	119.37
% TCDF Output to Pulp	39	40.66	23.27	0.590	90.70	22.34	38.90	59.15	73.96
% TCDF Output to Sludge	39	37.67	23.67	0.613	93.81	19.79	36.92	54.39	71.93
% TCDF Output to Effluent	39	21.68	18.74	2.264	77.28	7.76	15.25	26.64	52.38

WASTEWATER TREATMENT=ASB

TCDF Exports	N	Mean	Std	Minimum	Maximum	Lower Quartile	Median	Upper Quartile	90^{th} Percentile
TCDF in Pulp (lbs/day)*10^6	48	205.26	456.76	0.319	2523.00	7.04	38.97	159.57	631.57
TCDF in Sludge (lbs/day)*10^6	48	111.53	373.28	0.000	2394.00	1.67	38.97	37.66	259.60
TCDF in Effluent (lbs/day)*10^6	45	154.44	321.38	0.417	1542.00	5.02	31.79	124.67	490.88
Total TCDF (lbs/day)*10^6	45	486.64	967.80	2.128	4511.00	26.68	96.39	428.10	1940.00
TCDF in Pulp (lbs/ton ADBSP)*10^9	48	27.68	85.11	0.050	524.01	0.72	3.94	13.35	75.45
TCDF in Sludge (lbs/ton ADBSP)*10^9	48	10.55	31.64	0.000	195.59	0.12	0.70	3.99	36.60
TCDF in Effluent (lbs/ton ADBSP)*10^9	45	19.87	59.20	0.048	365.71	0.70	1.99	11.32	41.48
Total TCDF (lbs/ton ADBSP)*10^9	45	60.21	160.73	0.147	953.88	3.06	8.44	34.85	158.67
% TCDF Output to Pulp	45	45.77	22.76	4.383	92.18	24.66	45.54	63.07	77.97
% TCDF Output to Sludge	45	19.50	23.96	0.000	91.35	2.87	6.73	26.75	62.27
% TCDF Output to Effluent	45	34.74	20.53	0.323	74.99	15.17	32.83	52.38	66.01

FIGURE 5-1

% OUTPUT BY MATRIX

TCDD

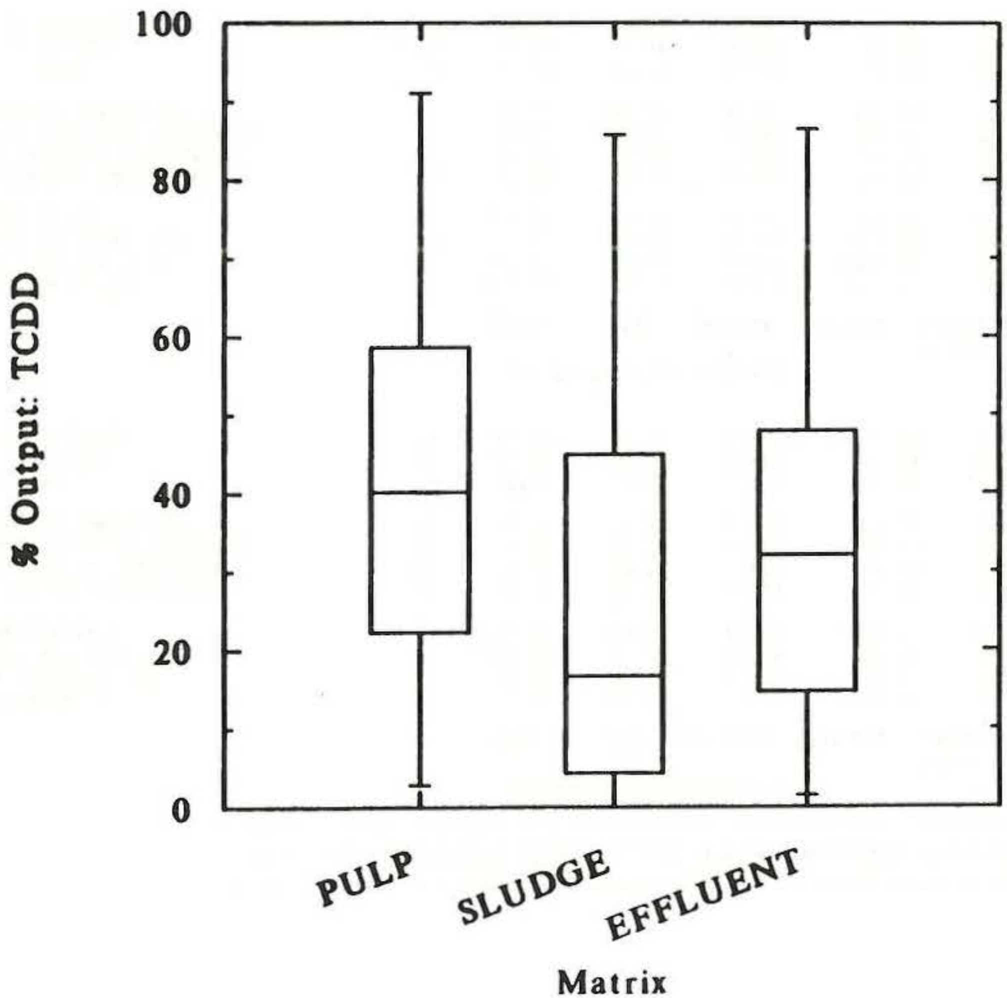


FIGURE 5-2

% OUTPUT BY MATRIX

TCDF

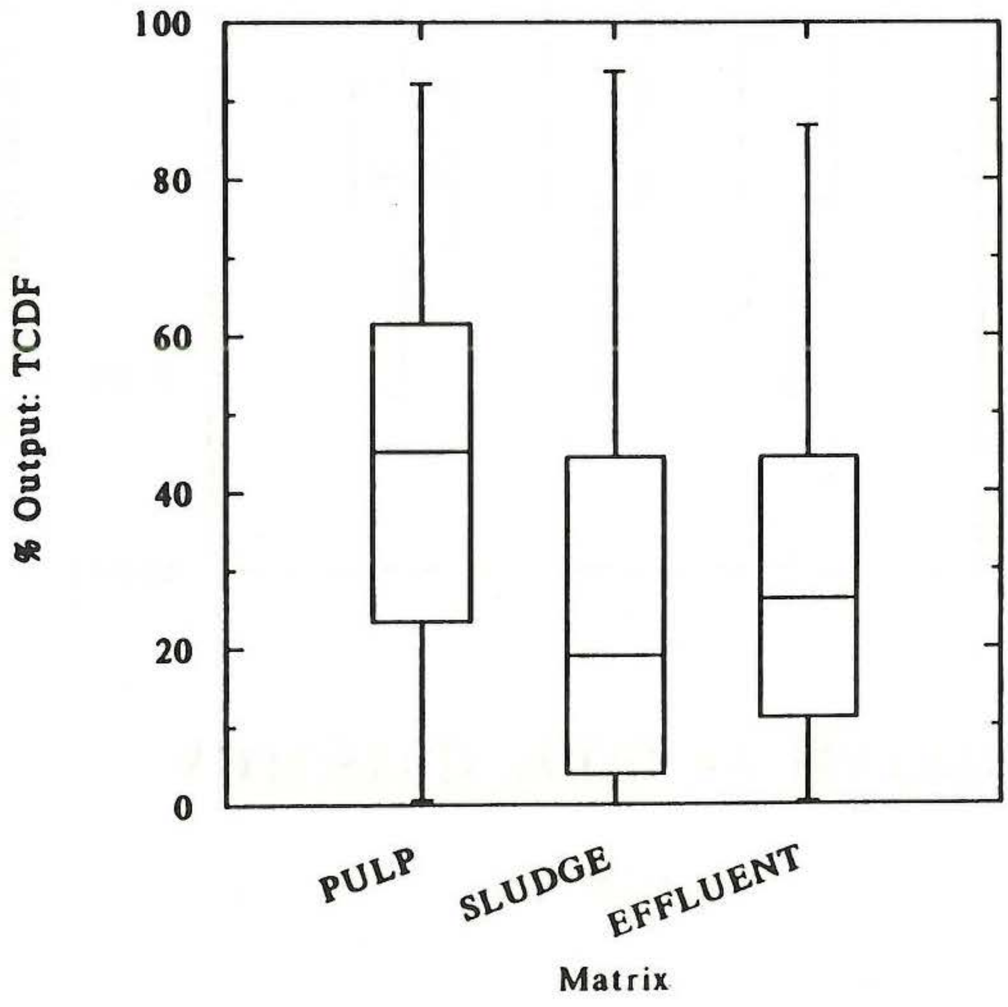


FIGURE 5-3

ADJUSTED TCDD BY MATRIX

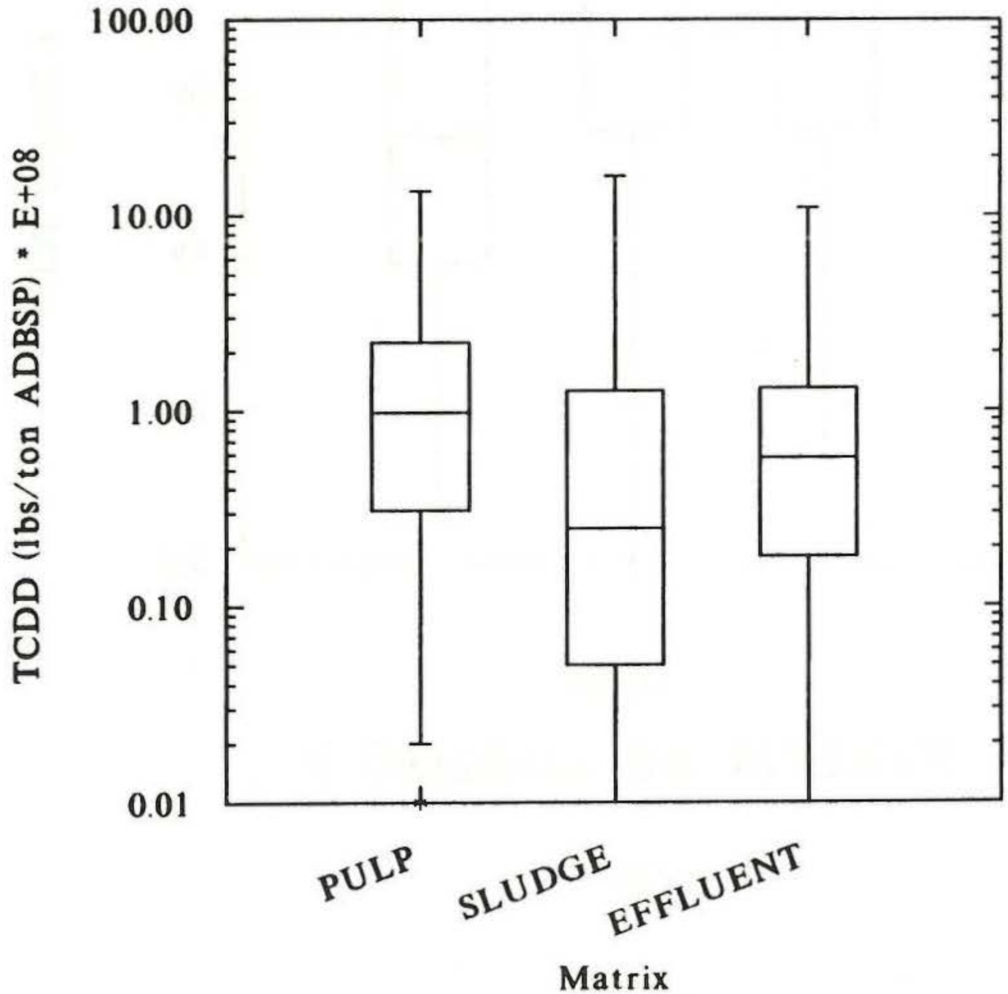


FIGURE 5-4

ADJUSTED TCDF BY MATRIX

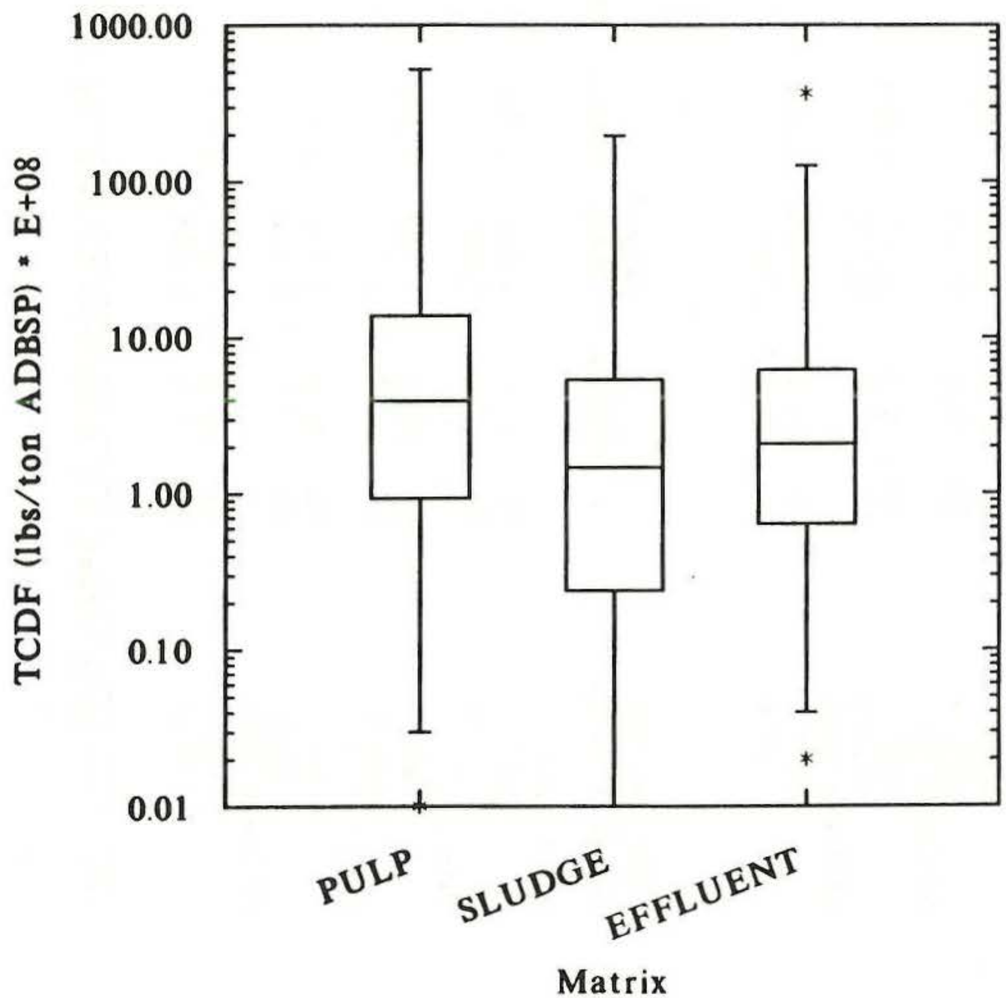


TABLE 5-5. DIFFERENCES BETWEEN PULPING PROCESSES

KRAFT vs SULFITE

TCDD Exports (lbs/day) * 10^6	N	Median	Logged Mean	t-stat	p-value
Total TCDD					
Kraft	79	24.4	1.355	7.371	.000
Sulfite	14	2.4	0.411		
Pulp TCDD					
Kraft	84	10.8	0.892	7.804	.000
Sulfite	15	0.2	-0.426		
Sludge TCDD					
Kraft	76	10.8	0.474	3.324	.003
Sulfite	14	0.2	-0.191		
Effluent TCDD					
Kraft	80	5.8	0.714	5.365	.000
Sulfite	15	0.8	-0.122		

TCDF Exports (lbs/day) * 10^6	N	Median	Logged Mean	t-stat	p-value
Total TCDF					
Kraft	79	98.8	2.021	4.363	.000
Sulfite	14	9.2	1.050		
Pulp TCDF					
Kraft	85	35.8	1.588	4.259	.001
Sulfite	15	2.0	0.302		
Sludge TCDF					
Kraft	76	35.8	1.120	2.405	.027
Sulfite	14	2.0	0.466		
Effluent TCDF					
Kraft	81	22.0	1.340	3.434	.003
Sulfite	15	1.6	0.416		

Note: Two-sample t-tests for difference between logged means

TABLE 5-5. DIFFERENCES BETWEEN PULPING PROCESSES (CONTINUED)

KRAFT vs SULFITE

TCDD Exports (lbs/ton ADBSP) * 10^8	N	Median	Logged Mean	t-stat	p-value
Total TCDD					
Kraft	79	2.8	0.420	4.792	.000
Sulfite	14	0.5	-0.192		
Pulp TCDD					
Kraft	84	1.2	-0.028	5.530	.000
Sulfite	15	0.1	-1.010		
Sludge TCDD					
Kraft	76	0.25	-0.478	1.527	.140
Sulfite	14	0.16	-0.794		
Effluent TCDD					
Kraft	80	0.6	-0.212	3.677	.001
Sulfite	15	0.2	-0.705		

TCDF Exports (lbs/ton ADBSP) * 10^8	N	Median	Logged Mean	t-stat	p-value
Total TCDF					
Kraft	79	10.4	1.087	3.026	.007
Sulfite	14	3.5	0.447		
Pulp TCDF					
Kraft	85	4.3	0.664	3.044	.008
Sulfite	15	0.4	-0.281		
Sludge TCDF					
Kraft	76	1.3	0.169	1.097	.286
Sulfite	14	1.4	-0.137		
Effluent TCDF					
Kraft	81	2.5	0.414	2.389	.028
Sulfite	15	0.7	-0.167		

Note: Two-sample t-tests for difference between logged means

FIGURE 5-5

% OUTPUT BY TREATMENT

EFFLUENT TCDD

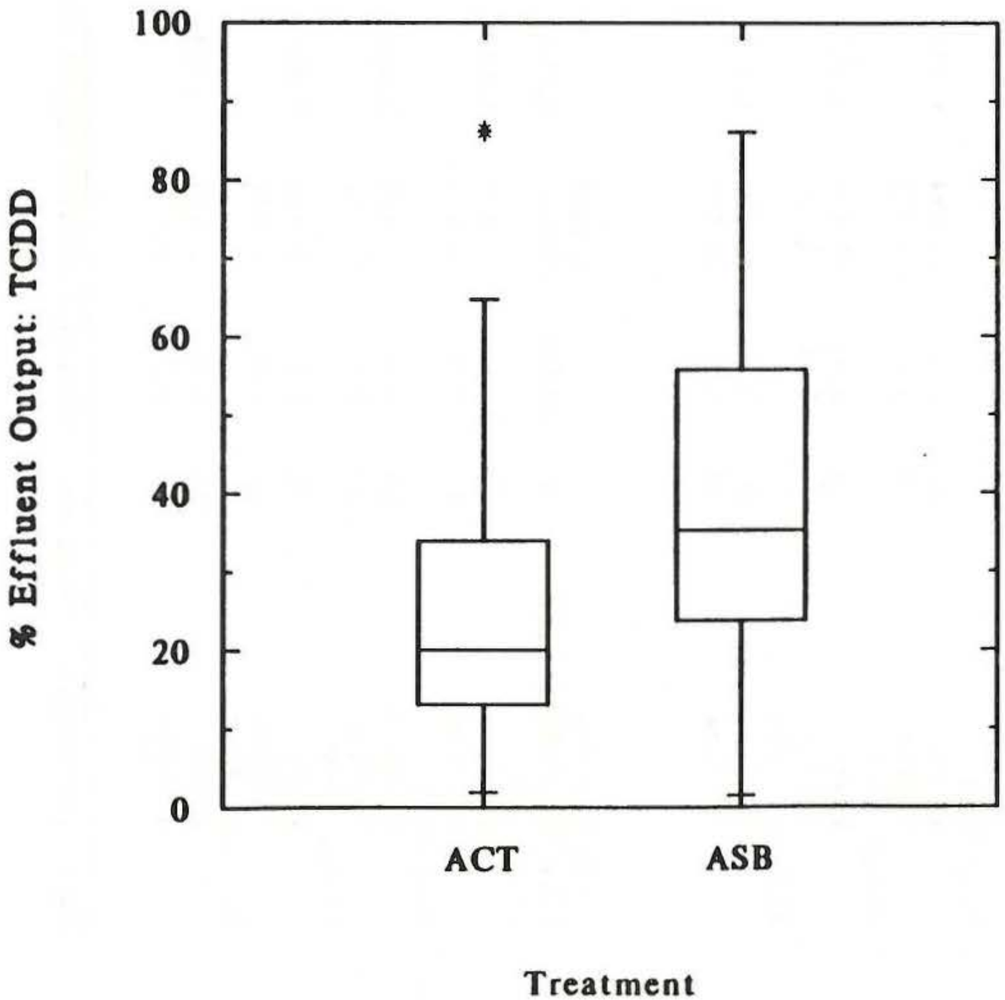


FIGURE 5-6

% OUTPUT BY TREATMENT

SLUDGE TCDD

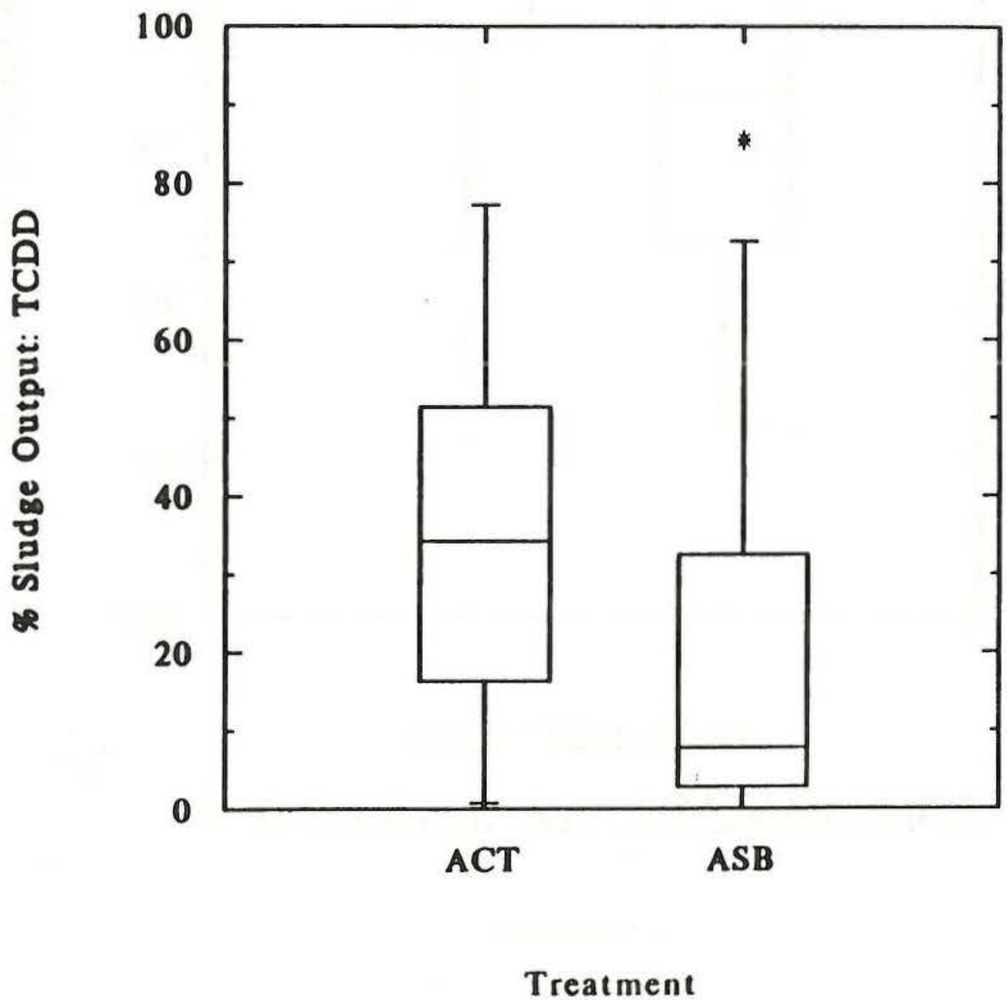


FIGURE 5-7

% OUTPUT BY TREATMENT

EFFLUENT TCDF

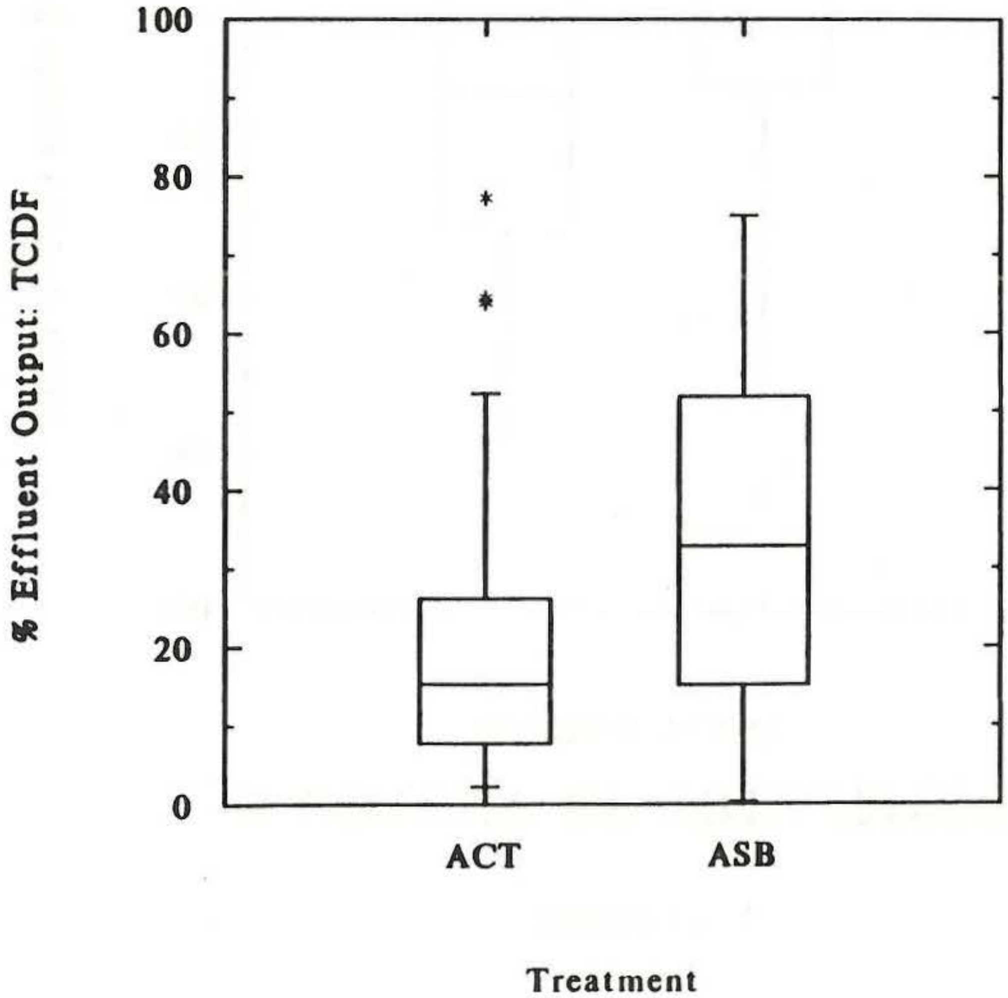


FIGURE 5-8

% OUTPUT BY TREATMENT

SLUDGE TCDF

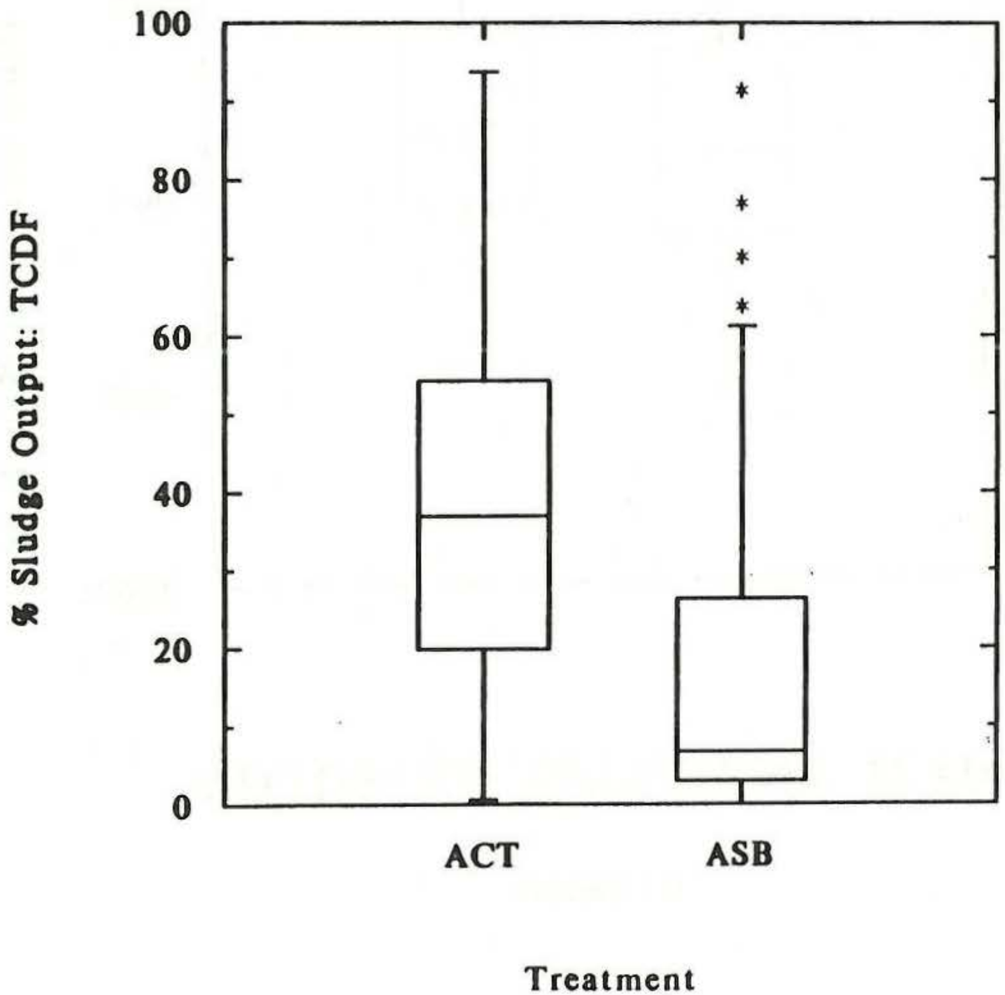


FIGURE 5-9

ADJUSTED EFFLUENT TCDD

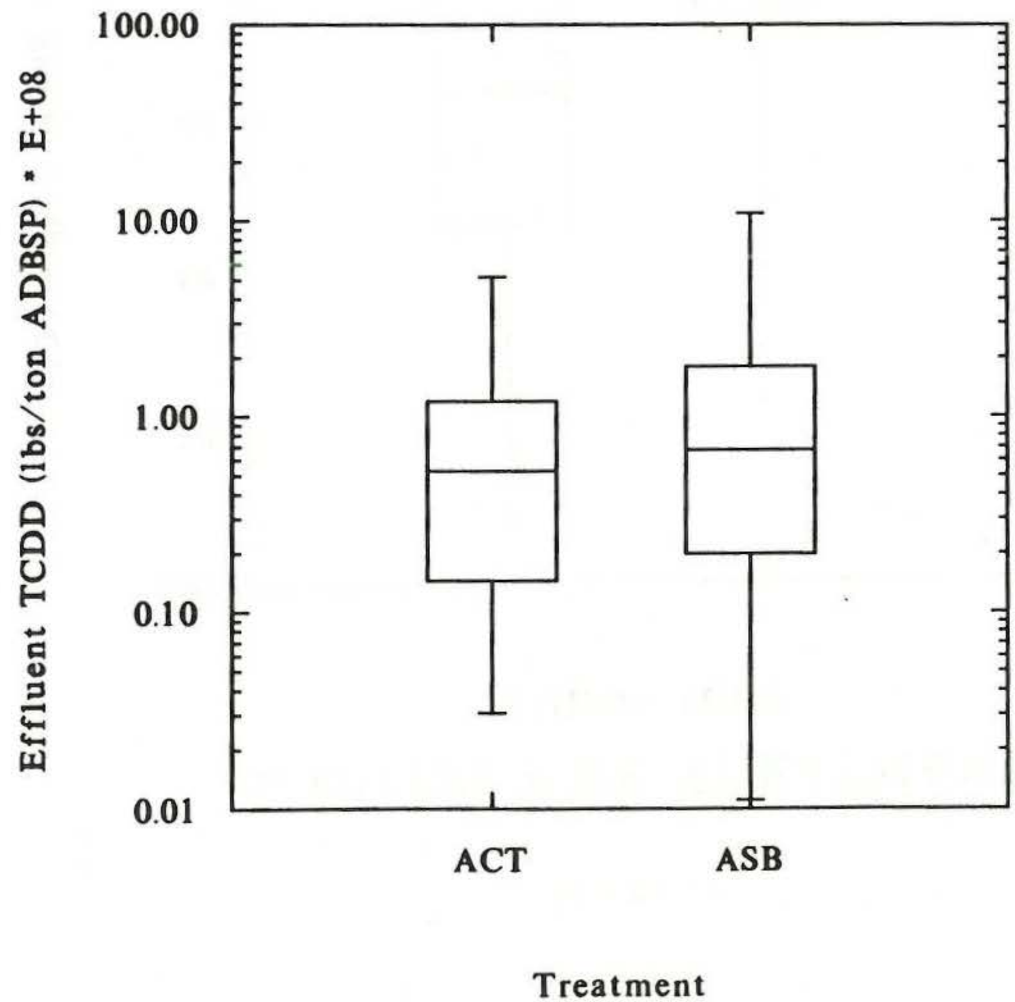


FIGURE 5-10

ADJUSTED SLUDGE TCDD

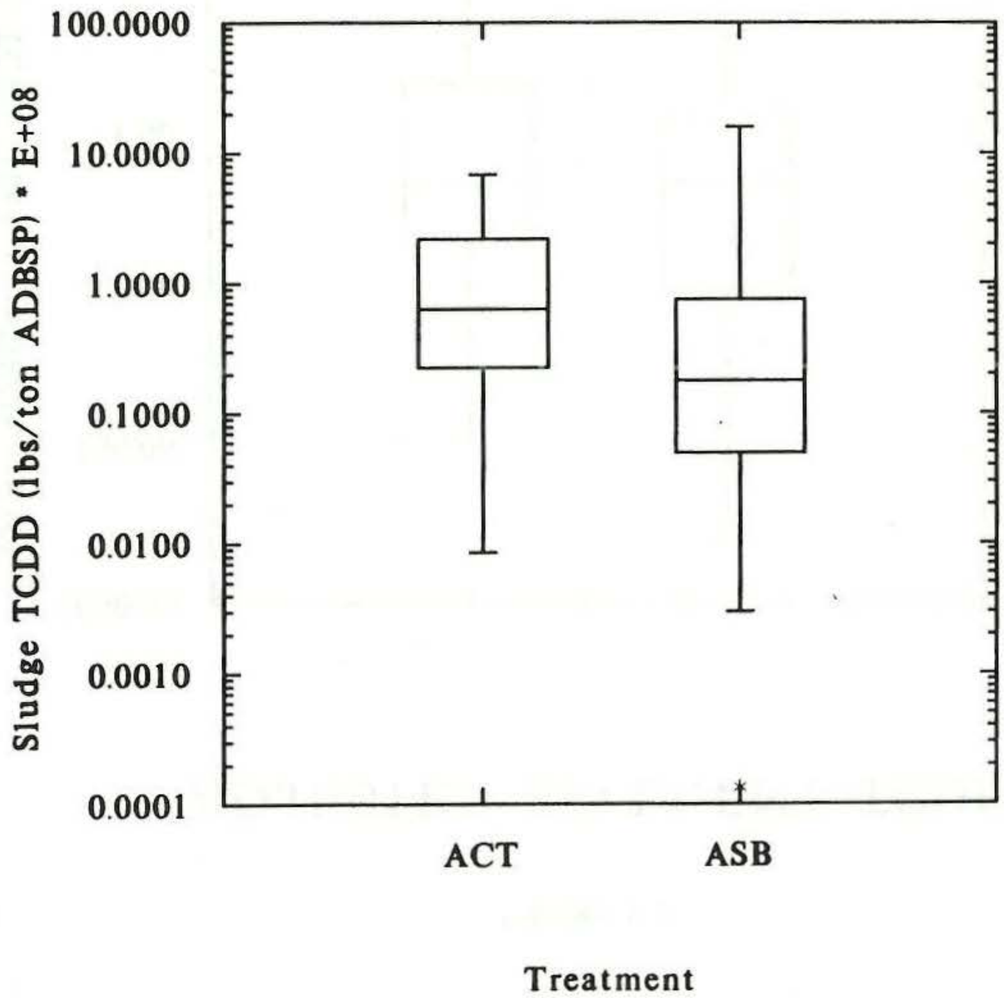


FIGURE 5-11

ADJUSTED EFFLUENT TCDF

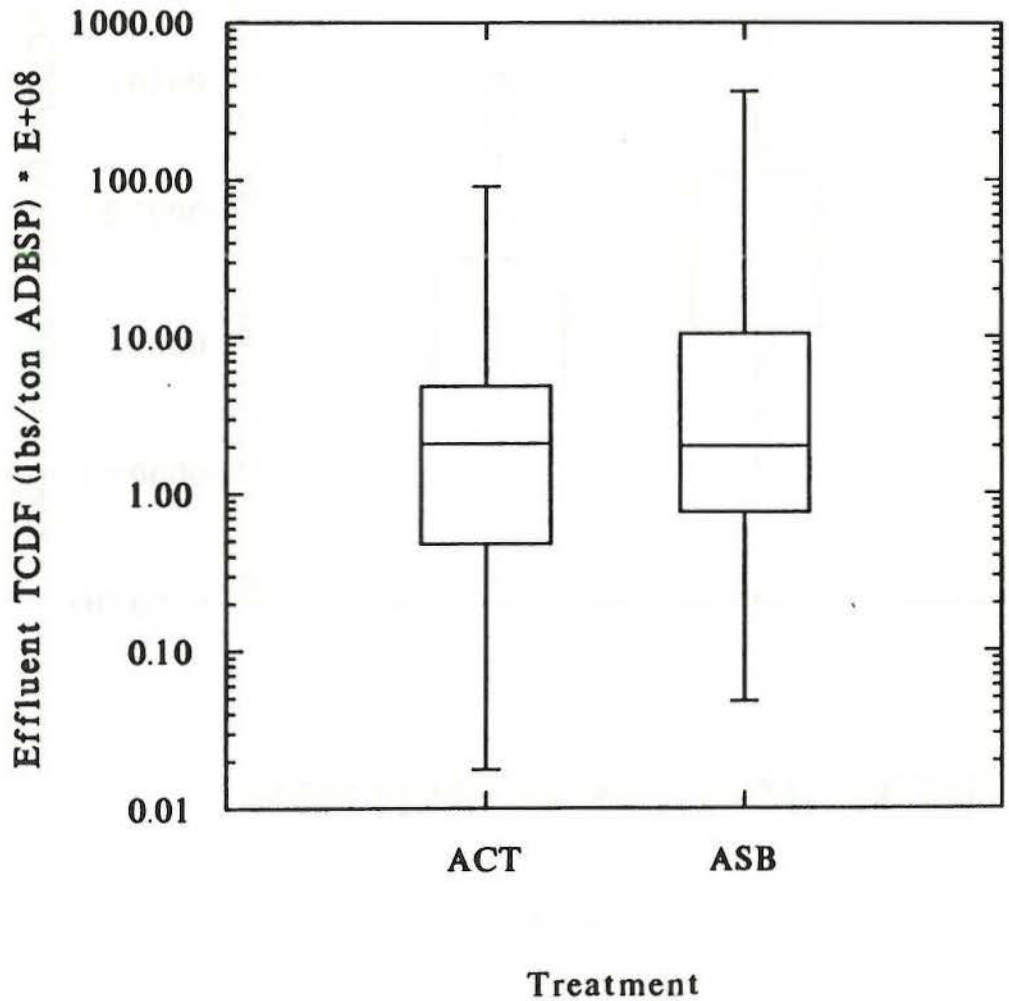


FIGURE 5-12

ADJUSTED SLUDGE TCDF

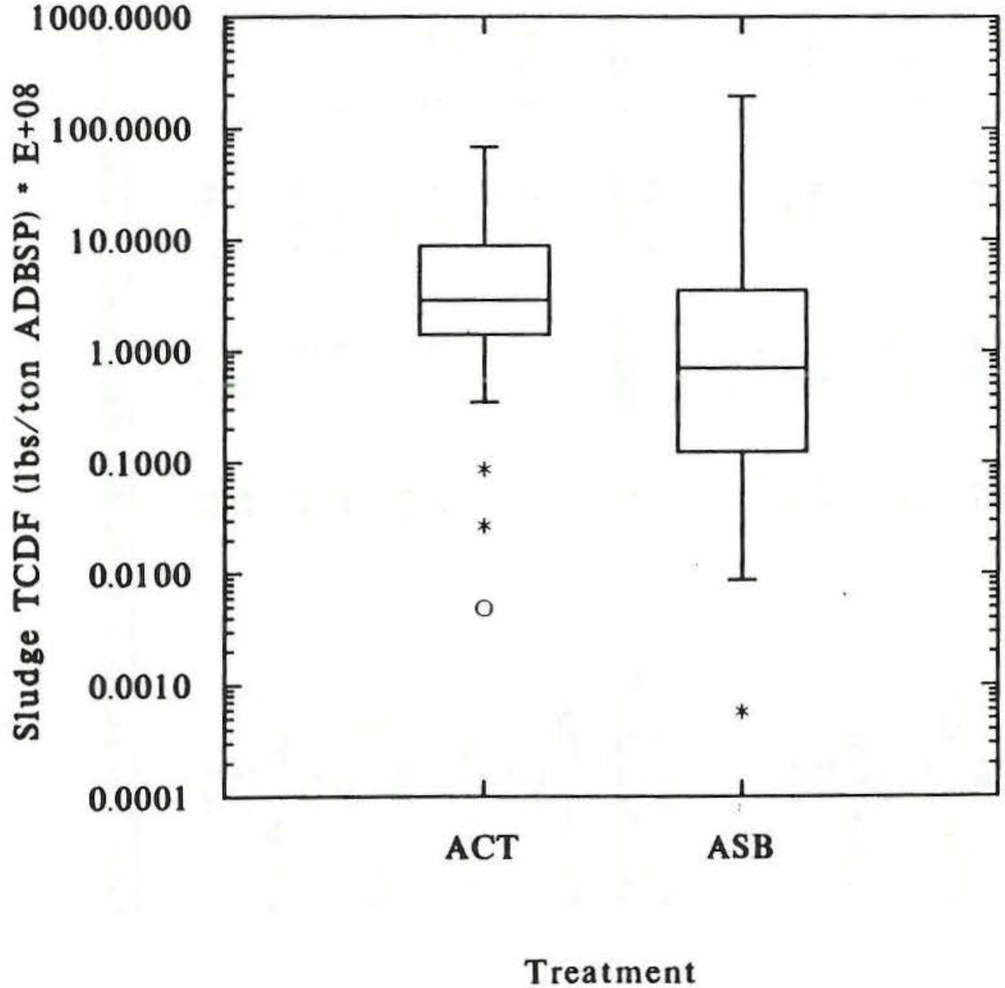


TABLE 5-6. DIFFERENCES BETWEEN TREATMENT TYPES

ACT vs ASB

All Mills (lbs/day) * 10^6	N	Median	Logged Mean	t-stat	p-value
Effluent TCDD					
ACT	40	2.9	0.409	-2.583	.012
ASB	43	9.4	0.820		
Sludge TCDD					
ACT	39	7.3	0.566	1.245	.217
ASB	45	11.4	0.324		
Effluent TCDF					
ACT	42	12.0	1.111	-1.456	.149
ASB	41	31.8	1.403		
Sludge TCDF					
ACT	39	28.4	1.230	1.262	.211
ASB	45	39.0	0.954		

Kraft Mills (lbs/day) * 10^6	N	Median	Logged Mean	t-stat	p-value
Effluent TCDD					
ACT	28	4.5	0.625	-1.438	.156
ASB	41	10.3	0.862		
Sludge TCDD					
ACT	28	5.8	0.829	2.459	.016
ASB	42	2.0	0.341		
Effluent TCDF					
ACT	29	22.8	1.337	-0.489	.627
ASB	41	31.8	1.434		
Sludge TCDF					
ACT	28	33.7	1.525	2.745	.008
ASB	42	6.6	0.938		

Note: Two-sample t-tests for difference between logged means

TABLE 5-6. DIFFERENCES BETWEEN TREATMENT TYPES (CONTINUED)

ACT VS. ASB

All Mills (lbs/ton ADBSP) * 10^8	N	Median	Logged Mean	t-stat	p-value
Effluent TCDD					
ACT	40	0.5	-0.351	-1.201	.233
ASB	43	0.7	-0.191		
Sludge TCDD					
ACT	39	0.6	-0.205	2.672	.009
ASB	45	0.2	-0.699		
Effluent TCDF					
ACT	41	2.1	0.238	-1.074	.286
ASB	44	2.0	0.436		
Sludge TCDF					
ACT	39	2.9	0.458	2.462	.016
ASB	45	0.7	-0.069		

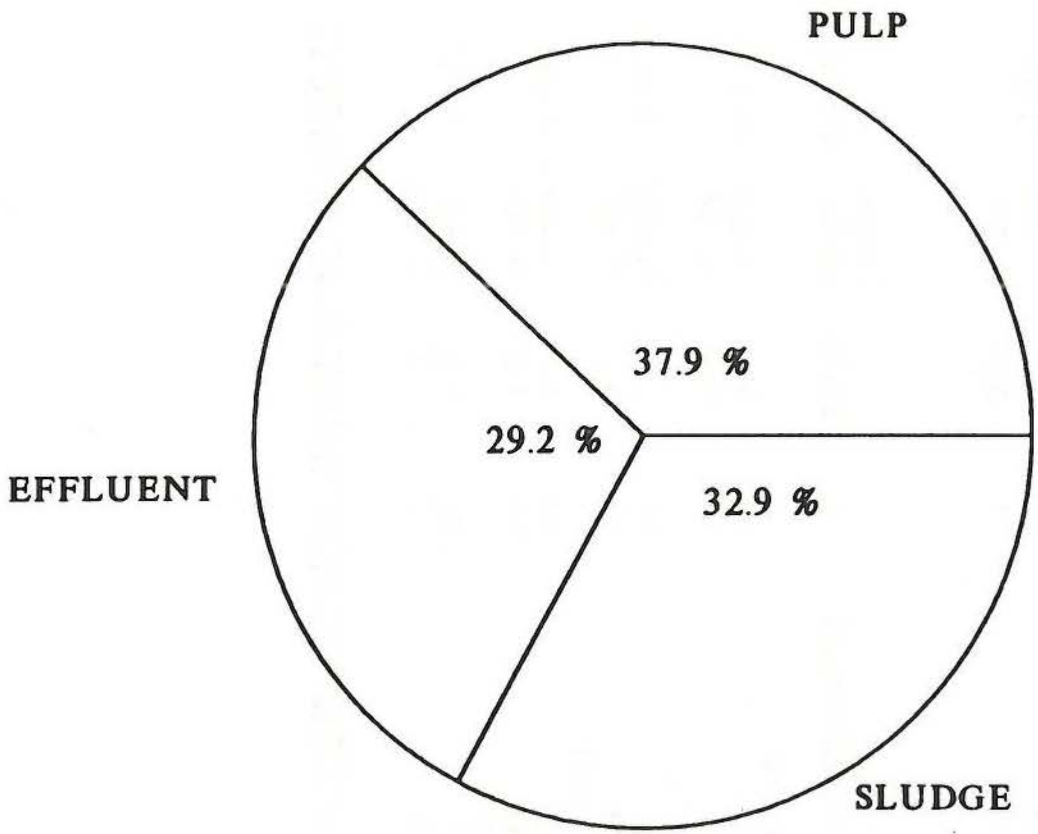
Kraft Mills (lbs/ton ADBSP) * 10^8	N	Median	Logged Mean	t-stat	p-value
Effluent TCDD					
ACT	28	0.6	-0.219	-0.430	.668
ASB	41	0.9	-0.158		
Sludge TCDD					
ACT	28	1.0	-0.015	3.518	.001
ASB	42	0.2	-0.687		
Effluent TCDF					
ACT	29	3.1	0.489	0.388	.699
ASB	41	2.0	0.415		
Sludge TCDF					
ACT	28	5.0	0.681	3.612	.001
ASB	42	0.8	-0.090		

Note: Two-sample t-tests for difference between logged means

FIGURE 5-13

TOTAL TCDD EXPORTS (lbs/day) * E+06

ALL MILLS INCLUDED



MATRIX	SUM
PULP	1.517
SLUDGE	1.319
EFFLUENT	1.170
TOTAL	4.006

FIGURE 5-14

TOTAL OUTPUT: TCDD

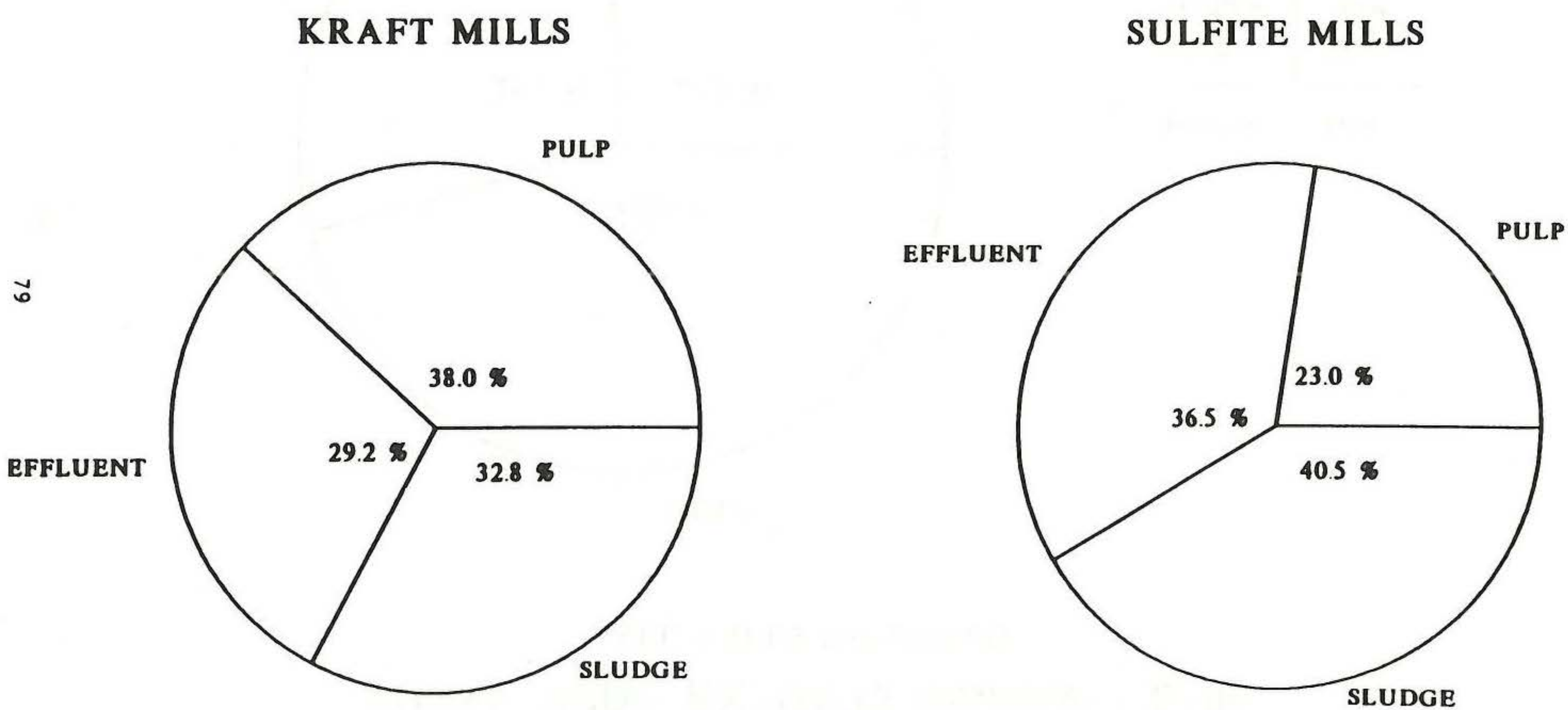
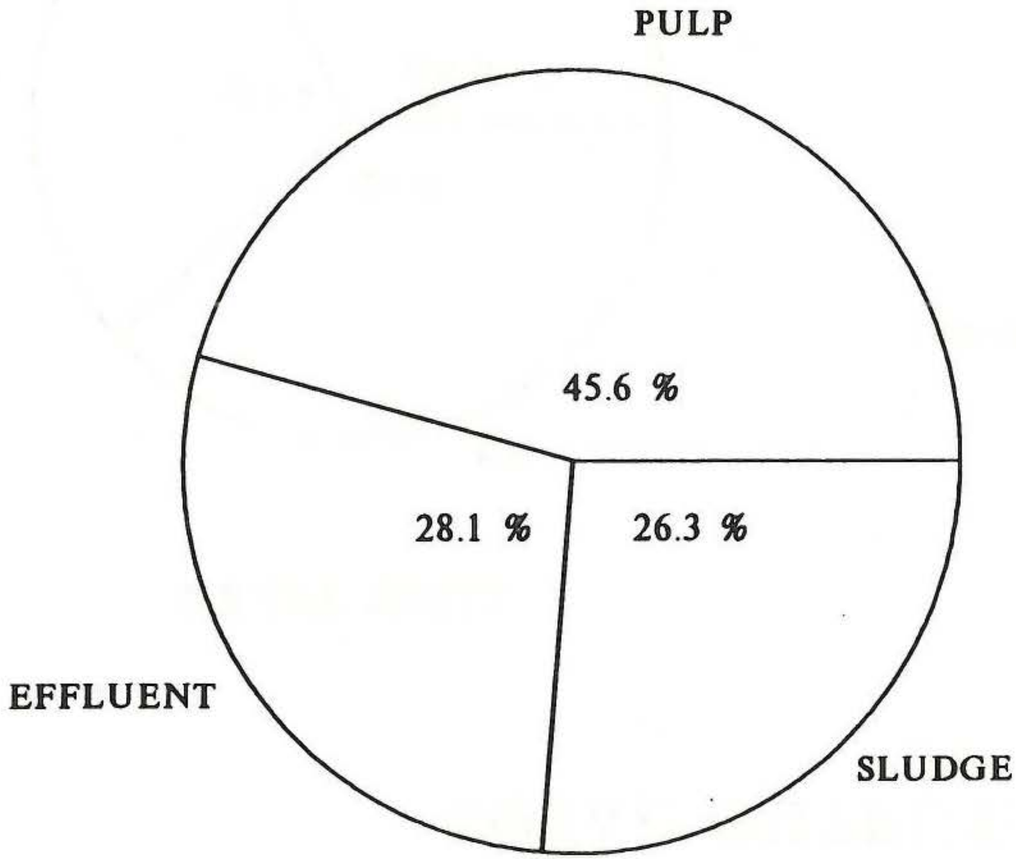


FIGURE 5-15

TOTAL TCDF EXPORTS (lbs/day) * E+06

ALL MILLS INCLUDED

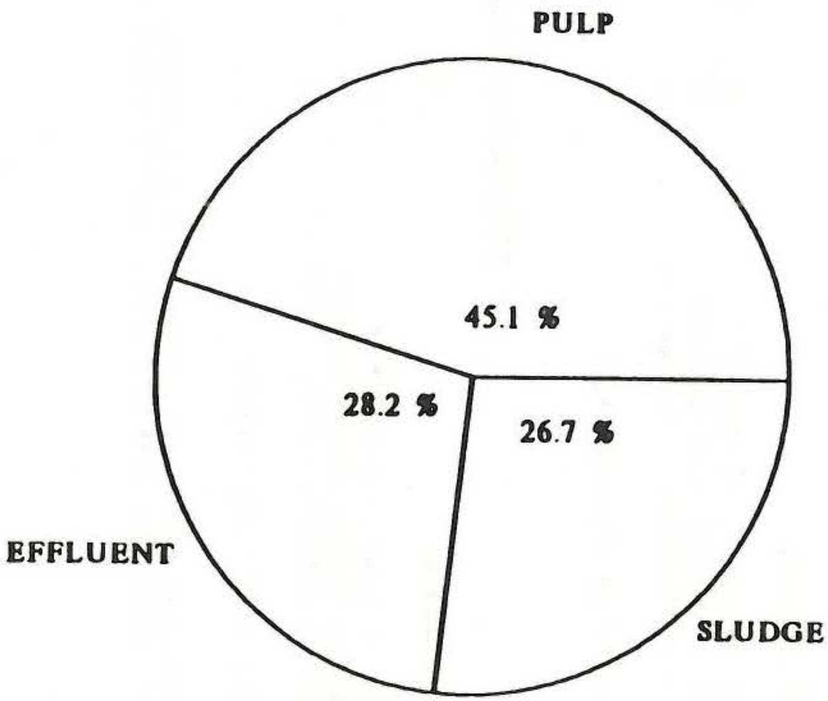


MATRIX	SUM
PULP	14.642
SLUDGE	8.429
EFFLUENT	9.024
TOTAL	32.095

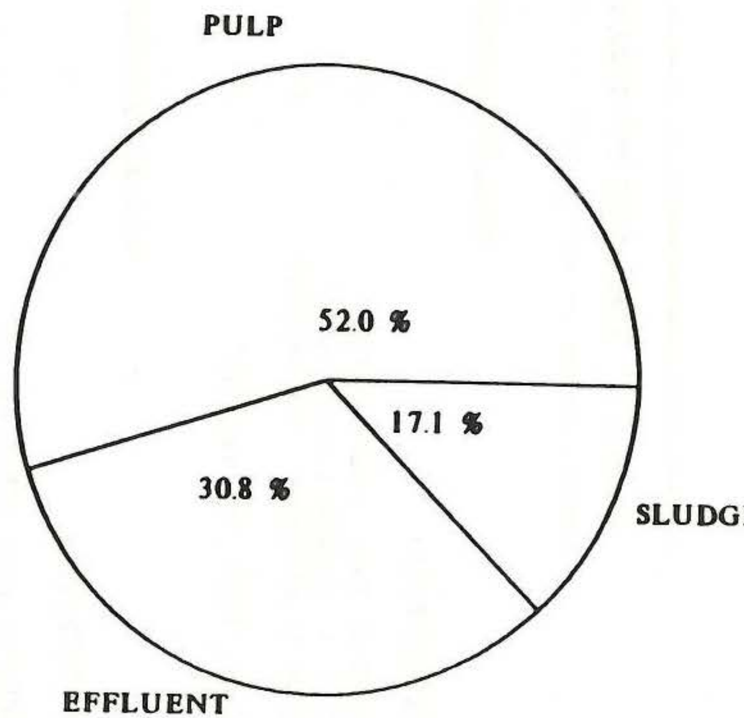
FIGURE 5-16

TOTAL OUTPUT: TCDF

KRAFT MILLS



SULFITE MILLS



Note: Percentages may not add to 100% due to rounding error.

TABLE 5-7. STATISTICS FOR TCDD/TCDF (BY MILL PROCESS)

Mill Process=Kraft

TCDD Exports	N	Sum	Mean	%(Total)
TCDD in Pulp (lbs/day)*10^6	80	1,486	18.6	38.0
TCDD in Sludge (lbs/day)*10^6	80	1,280	16.0	32.8
TCDD in Effluent (lbs/day)*10^6	80	1,141	14.3	29.2
Total TCDD (lbs/day)*10^6	80	3,907	48.8	100.0

Mill Process=Sulfite

TCDD Exports	N	Sum	Mean	%(Total)
TCDD in Pulp (lbs/day)*10^6	14	12	0.9	23.0
TCDD in Sludge (lbs/day)*10^6	14	22	1.6	40.5
TCDD in Effluent (lbs/day)*10^6	14	19	1.4	36.5
Total TCDD (lbs/day)*10^6	14	53	3.8	100.0

Mill Process=Kraft

TCDF Exports	N	Sum	Mean	%(Total)
TCDF in Pulp (lbs/day)*10^6	80	13,525	169.1	45.1
TCDF in Sludge (lbs/day)*10^6	80	7,996	100.0	26.7
TCDF in Effluent (lbs/day)*10^6	80	8,475	105.9	28.2
Total TCDF (lbs/day)*10^6	80	29,996	374.9	100.0

Mill Process=Sulfite

TCDF Exports	N	Sum	Mean	%(Total)
TCDF in Pulp (lbs/day)*10^6	14	649	46.4	52.0
TCDF in Sludge (lbs/day)*10^6	14	214	15.3	17.1
TCDF in Effluent (lbs/day)*10^6	14	384	27.5	30.8
Total TCDF (lbs/day)*10^6	14	1,248	89.1	100.0

Note: Discrepancies may result due to rounding errors.

TABLE 5-8. STATISTICS FOR TCDD/TCDF (BY MILL PROCESS)

Mill Process=Kraft

TCDD Exports	N	Sum	Mean	%(Total)
TCDD in Pulp (lbs/ton ADBSP)*10^8	80	158	2.0	40.7
TCDD in Sludge (lbs/ton ADBSP)*10^8	80	119	1.5	30.7
TCDD in Effluent (lbs/ton ADBSP)*10^8	80	111	1.4	28.6
Total TCDD (lbs/ton ADBSP)*10^8	80	388	4.9	100.0

Mill Process=Sulfite

TCDD Exports	N	Sum	Mean	%(Total)
TCDD in Pulp (lbs/ton ADBSP)*10^8	14	4	0.3	30.6
TCDD in Sludge (lbs/ton ADBSP)*10^8	14	5	0.4	36.0
TCDD in Effluent (lbs/ton ADBSP)*10^8	14	5	0.3	33.4
Total TCDD (lbs/ton ADBSP)*10^8	14	14	1.0	100.0

Mill Process=Kraft

TCDF Exports	N	Sum	Mean	%(Total)
TCDF in Pulp (lbs/ton ADBSP)*10^8	80	1,902	23.8	49.2
TCDF in Sludge (lbs/ton ADBSP)*10^8	80	819	10.2	21.2
TCDF in Effluent (lbs/ton ADBSP)*10^8	80	1,145	14.3	29.6
Total TCDF (lbs/ton ADBSP)*10^8	80	3,866	48.3	100.0

Mill Process=Sulfite

TCDF Exports	N	Sum	Mean	%(Total)
TCDF in Pulp (lbs/ton ADBSP)*10^8	14	97	6.9	50.3
TCDF in Sludge (lbs/ton ADBSP)*10^8	14	41	2.9	21.1
TCDF in Effluent (lbs/ton ADBSP)*10^8	14	55	4.0	28.7
Total TCDF (lbs/ton ADBSP)*10^8	14	193	13.8	100.0

Note: Discrepancies may result due to rounding errors.

6. ANALYSIS OF TOTAL SUSPENDED SOLIDS

Since the preceding analysis uncovered differences between treatment types Activated Sludge Wastewater Treatment (ACT) and Aerated Stabilization Basins (ASB) with regard to the rates at which 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) and 2,3,7,8-tetrachlorodibenzofuran (TCDF) were exported to sludge and effluent vectors, a more extensive analysis was made on a measured variable suspected to affect wastewater treatment performance: total suspended solids (TSS). It has been suggested that ACT and ASB treatments differ significantly with regard to average TSS levels, so the goal of the analysis in section 6 was to assess any potential relationship between TCDD/TCDF formation in sludge and effluent and total suspended solids levels at the waste treatment facilities.

Since important characteristics of kraft and sulfite mills were quite different, any potential relationship between TCDD/TCDF formation and TSS might be masked if both mill types were analyzed together. As it was, the number of sulfite mills was small, and only one sulfite mill with usable data employed an ASB-type waste treatment, so the analysis was confined to ACT-treated or ASB-treated kraft mills. (Please note that all figures and tables are located at the end of the text.)

Preliminary examination of the TSS data indicated that the distribution of values could be approximated by a lognormal density (appendix B). A subsequent two-sample t-test on the logged TSS values indicated that the average total suspended solids content of ACT systems was significantly higher than that for ASB systems at the 5 percent level. Variation in the TSS data by treatment type is shown in the boxplot of Figure 6-1; descriptive statistics for the TSS levels are provided in Table 6-1, classified by pulping process and wastewater treatment.

Given the observed difference in treatment types with respect to average TSS levels, the next step was to determine to what degree TSS levels could explain differences due to wastewater treatment in TCDD/TCDF mass outputs to sludge and effluent. Relationships between TSS and TCDD/TCDF mass exports to sludge and effluent were explored and tested for statistical significance. Using TSS as the independent variable, the dependent variables included TCDD/TCDF mass exports to sludge and effluent in both lbs/day and lbs/ton Air-Dried Brownstock Pulp (ADBSP).

Examination of the dependent variables and their distributional characteristics via probability plots indicated that the TCDD/TCDF mass output variables might reasonably be characterized by lognormal distributions (appendix B). Plots were then made of TSS versus each of the dependent variables on a log-log scale, which enabled estimation of regression equations from data that resembled bivariate normal scatterclouds, a prerequisite for using normal theory estimates of the stability of the regression lines.

Each of the scatterplots was overlaid with a best fitting linear regression and 90 percent confidence bands. The 90 percent confidence bands provide an approximate confidence interval for the estimated regression mean within the range of the data at each value along the independent axis. Computation of each confidence band was based upon the t-statistic for the estimated linear slope and the estimated standard error in the dependent variable at any given point x_0 along the independent axis.

Visual inspection of Figures 6-2 through 6-5 indicates that for any fixed TSS level, the variability from mill to mill in effluent and sludge TCDD/TCDF mass exports was substantial. The regression lines overlaying the plots estimated the average behavior of the TCDD/TCDF exports as TSS levels varied; however, none of the correlations between TSS and TCDD/TCDF exports was very strong. Clearly, TSS is not the only factor that affects amounts of TCDD/TCDF found in sludge and effluent, and it may not be a dominant factor.

The estimated regression equations are presented in Tables 6-2 and 6-3. Note that since the regressions were performed on the logged data, the relationships suggested are not linear in the original units. Rather, the model implies that when the slope coefficient is significantly different from zero, the TCDD/TCDF mass output is proportional to a <u>power</u> of the TSS level.

Tables 6-2 and 6-3 confirm that the correlations between TSS and the corresponding TCDD/TCDF mass outputs were rather weak. The largest fraction of explained variance (as indicated by the R^2 statistic) for any of the variables was less than 5 percent. The linear regressions suggest that TCDD/TCDF effluent mass rates increased somewhat with larger TSS levels, while TCDD/TCDF sludge mass rates decreased slightly as TSS increased. However, none of the estimated regression slopes were significantly different from zero at the 5 percent level. Very similar results were found for each matrix and analyte when considering either the unadjusted or adjusted mass export rates.

Since ASB and ACT-type treatments were combined in the previous plots, the last step in this section was to subdivide mills by waste treatment and recompute possible linear relationships between TSS and the TCDD/TCDF mass exports. This was considered important primarily because the sludge samples taken at ASB facilities consisted of primary sludge only, while those at ACT facilities consisted of composites samples of primary and secondary sludges. Figures 6-6 to 6-9 are redrawings of Figures 6-2 to 6-5 that indicate the type of waste treatment used at each scatterpoint (ACT or ASB), and a regression overlay corresponding to each wastewater subgroup. The separate regression equations for each type of waste treatment are presented in Tables 6-4 through 6-7.

For both wastewater treatment types, large TSS levels were somewhat associated with higher TCDD/TCDF exports to effluent and lower TCDD/TCDF exports to sludge. In each case, however, the data from ACT-type treatment facilities were more sharply sloped than data from ASB systems. These visual results were supported by the regression statistics listed in Tables 6-4 through 6-7. None of the estimated slopes for the ASB mills were significant at the 5 percent level; however, several of the relationships between TSS and TCDD/TCDF exports to sludge and effluent were significant for ACT mills. Again, the estimated correlations were weak, but in some cases total suspended solids accounted for close to 20 percent of the total variability in TCDD/TCDF mass sludge and effluent exports at mills using ACT treatment.

Based on this analysis, it is difficult to determine whether TSS influences the proportions of TCDD/TCDF mass exported to sludge and effluent vectors. The proportion of total variation in the TCDD/TCDF data explained by the TSS level (through the R^2 statistic) did not exceed 20 percent for any of the regressions calculated. It is also possible that other variables were present in these data that might have masked relationships between TSS and TCDD/TCDF exports. The study design did not permit a more complete analysis. However, there did appear at least a weak link between the TSS level and the TCDD/TCDF sludge and effluent export rates for kraft mills using ACT-type wastewater facilities. If such a link exists, the level of TSS may help to explain the observed differences between ASB and ACT waste treatments with respect to TCDD/TCDF found in sludge and effluent.

FIGURE 6-1

TSS BY TREATMENT

TREATED KRAFT MILLS ONLY

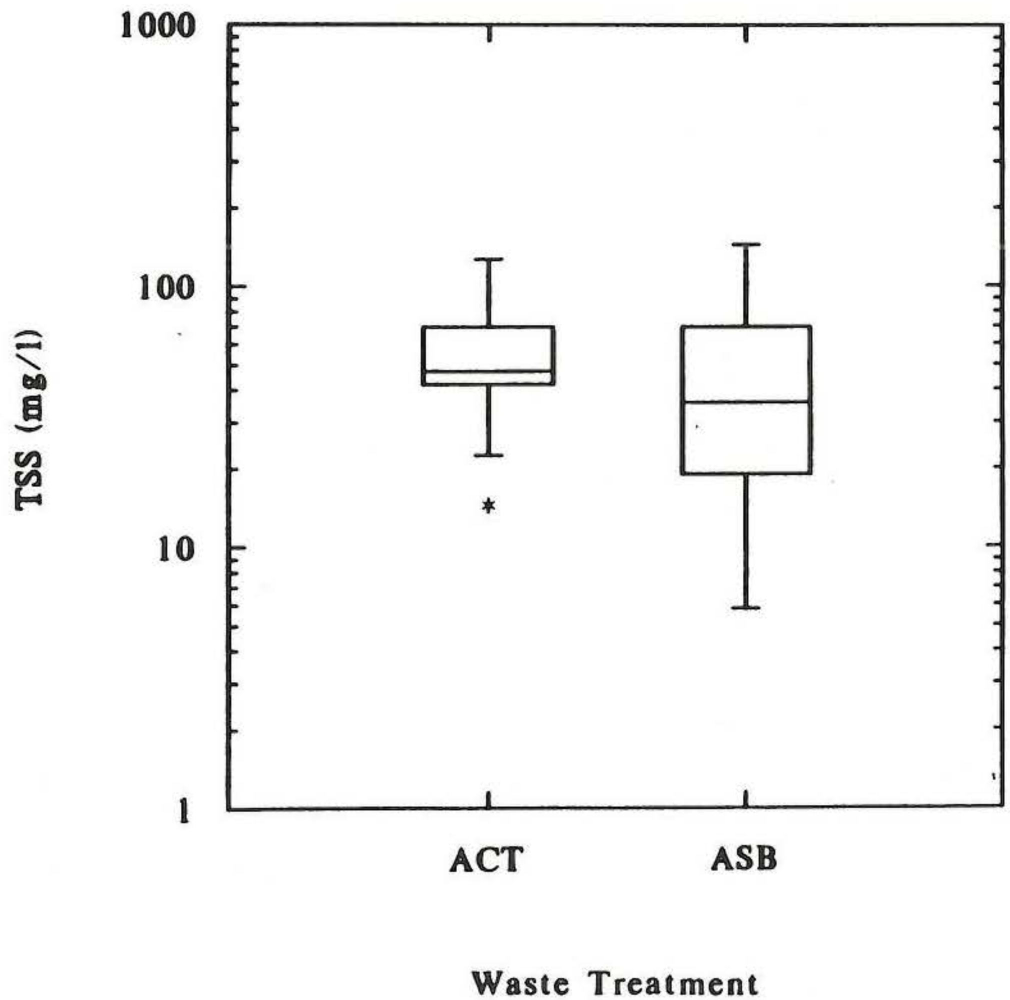


TABLE 6-1. DESCRIPTIVE STATISTICS FOR TSS

	N	Mean	Std	Minimum	Maximum	Lower Quartile	Median	Upper Quartile	90th Percentile
All Mills	81	61.50	50.48	5.800	273.00	25.63	46.30	81.15	126.72
Kraft Mills	67	52.61	36.19	5.800	144.60	22.40	45.80	70.00	115.40
ACT	25	60.02	34.40	14.400	144.60	41.90	47.20	78.25	119.80
ASB	42	48.20	36.91	5.800	143.80	18.95	35.70	69.88	112.26
Sulfite Mills	12	111.85	85.69	26.800	273.00	32.44	87.05	182.20	264.18

FIGURE 6-2

EFFLUENT TCDD OUTPUT

TREATED KRAFT MILLS ONLY

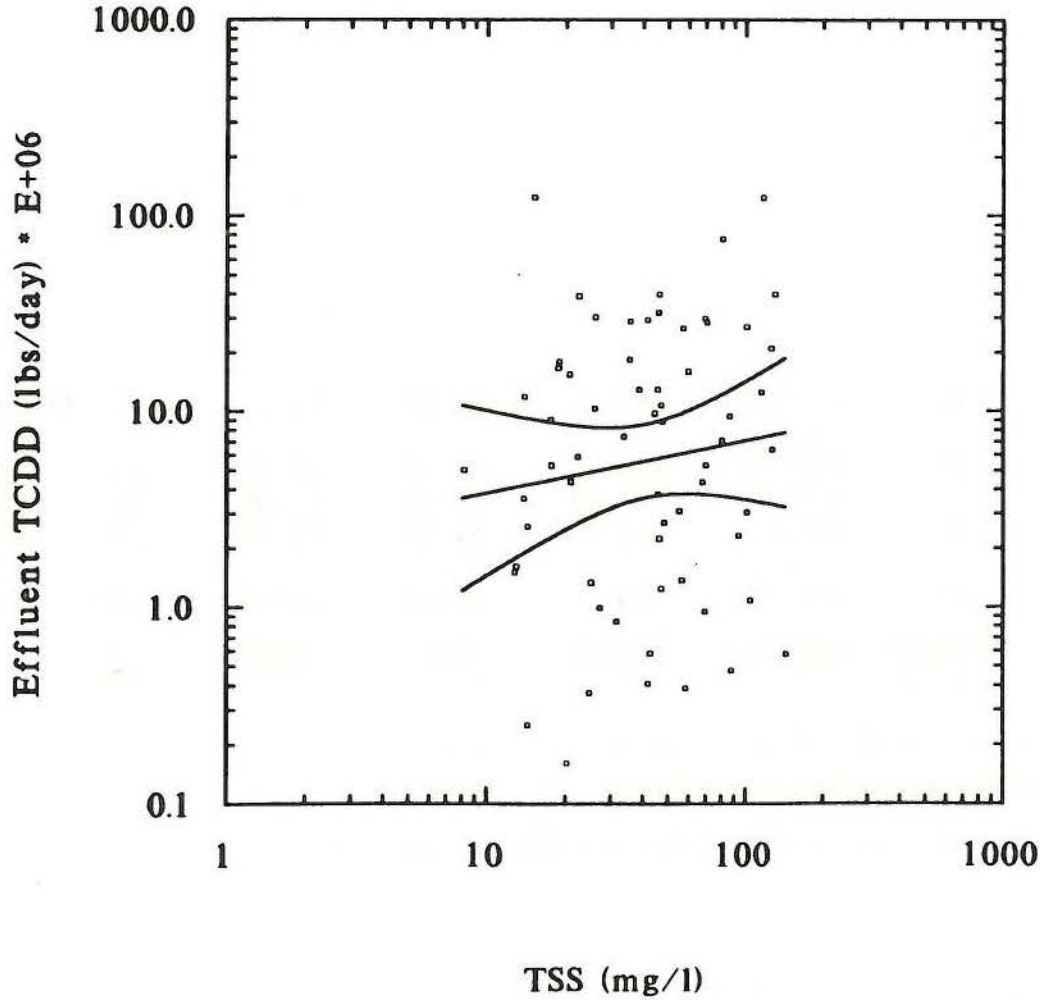


FIGURE 6-3

SLUDGE TCDD OUTPUT

TREATED KRAFT MILLS ONLY

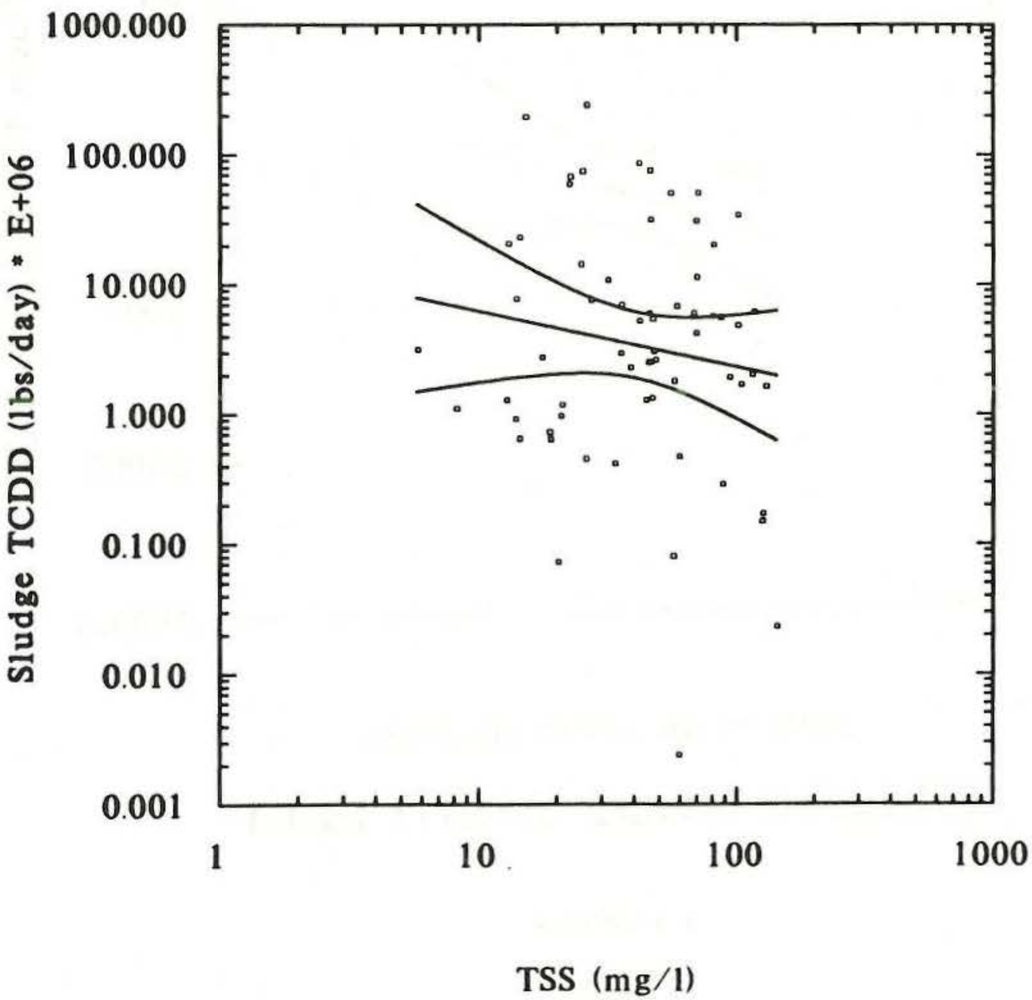


FIGURE 6-4

EFFLUENT TCDF OUTPUT

TREATED KRAFT MILLS ONLY

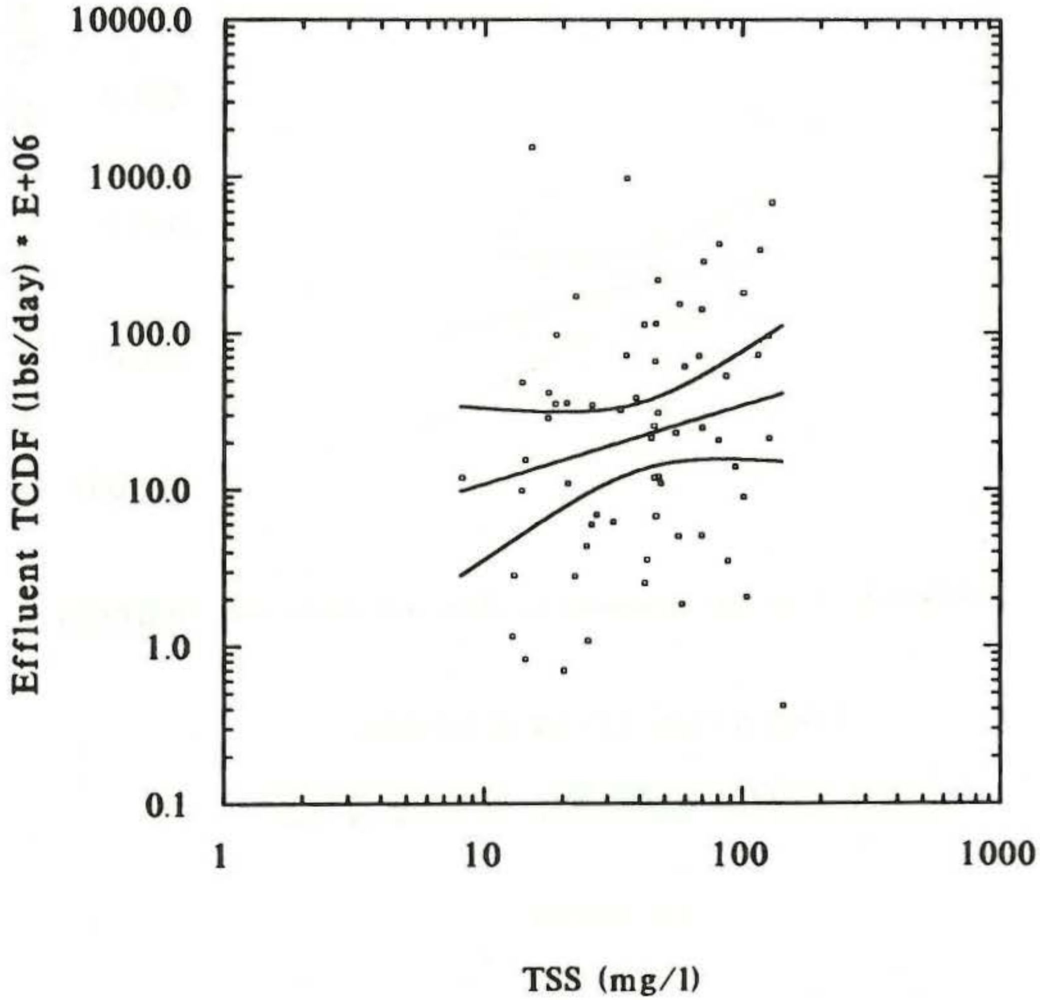


FIGURE 6-5

SLUDGE TCDF OUTPUT

TREATED KRAFT MILLS ONLY

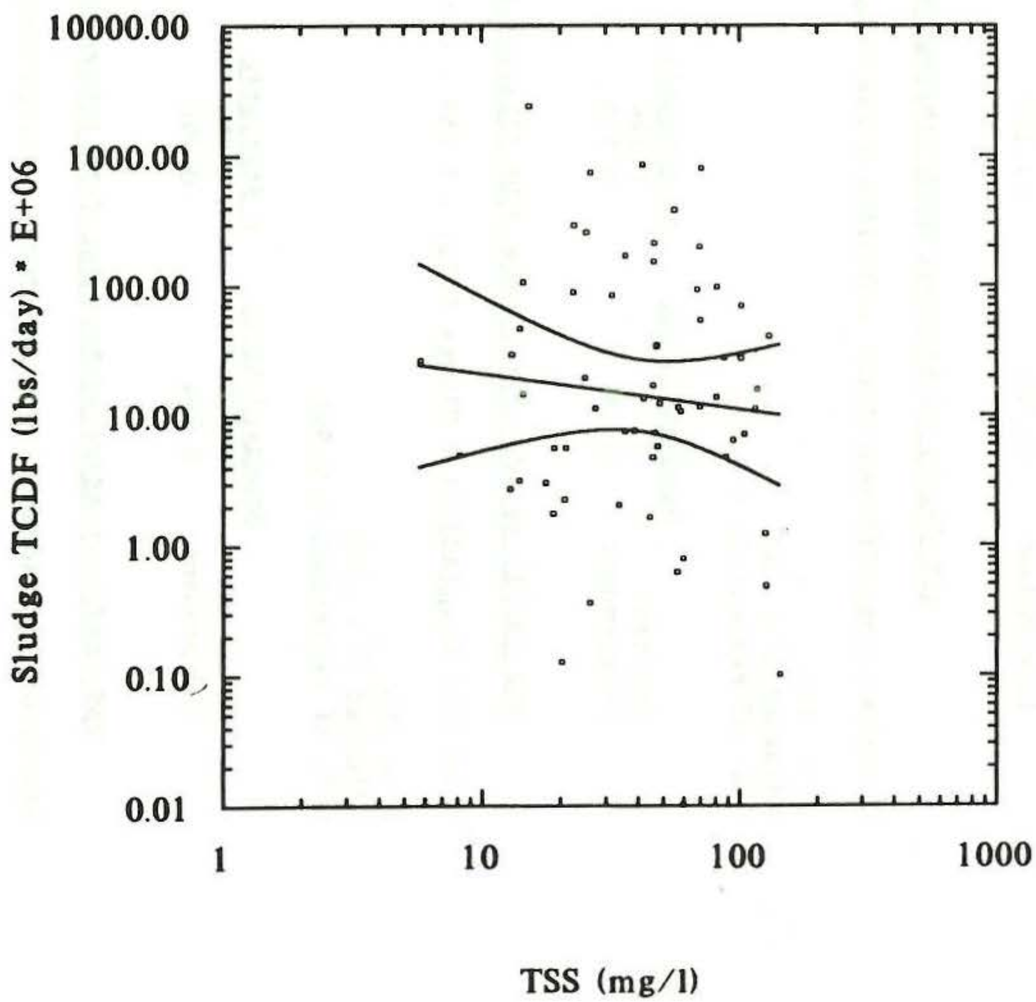


TABLE 6-2: TCDD EXPORTS (TREATED KRAFT MILLS ONLY)

TSS (mg/l) vs Sludge TCDD (lbs/day)*10^6

Equation: Log_{10}(Sludge TCDD) = 1.227 - 0.431 * Log_{10}(TSS)

R^2 = .022
Adjusted R^2 = .006
S.E. of Regression = 0.933

	Standard Error	t Statistic	p-Value
Constant	0.596	2.059	0.044
Independent	0.363	-1.187	0.240

TSS (mg/l) vs Effluent TCDD (lbs/day)*10^6

Equation: Log_{10}(Effluent TCDD) = 0.315 + 0.268 * Log_{10}(TSS)

R^2 = .014
Adjusted R^2 = .000
S.E. of Regression = 0.687

	Standard Error	t Statistic	p-Value
Constant	0.461	0.684	0.497
Independent	0.281	0.953	0.344

TSS (mg/l) vs Adjusted Sludge TCDD (lbs/ton ADBSP)*10^8

Equation: Log_{10}(Adjusted Sludge TCDD) = 0.157 - 0.373 * Log_{10}(TSS)

R^2 = .016
Adjusted R^2 = .000
S.E. of Regression = 0.961

	Standard Error	t Statistic	p-Value
Constant	0.614	0.256	0.798
Independent	0.374	-0.998	0.322

TSS (mg/l) vs Adjusted Effluent TCDD (lbs/ton ADBSP)*10^8

Equation: Log_{10}(Adjusted Effluent TCDD) = -0.713 + 0.311 * Log_{10}(TSS)

R^2 = .026
Adjusted R^2 = .010
S.E. of Regression = 0.589

	Standard Error	t Statistic	p-Value
Constant	0.396	-1.802	0.076
Independent	0.241	1.290	0.202

TABLE 6-3. TCDF EXPORTS (TREATED KRAFT MILLS ONLY)

TSS (mg/l) vs Sludge TCDF (lbs/day)*10^6

Equation: $\log_{10}$(Sludge TCDF) = 1.599 - 0.277 * $\log_{10}$(TSS)

R^2 = .008
Adjusted R^2 = .000
S.E. of Regression = 1.010

	Standard Error	t Statistic	p-Value
Constant	0.645	2.480	0.016
Independent	0.393	-0.704	0.484

TSS (mg/l) vs Effluent TCDF (lbs/day)*10^6

Equation: $\log_{10}$(Effluent TCDF) = 0.538 + 0.499 * $\log_{10}$(TSS)

R^2 = .037
Adjusted R^2 = .022
S.E. of Regression = 0.787

	Standard Error	t Statistic	p-Value
Constant	0.528	1.018	0.313
Independent	0.322	1.553	0.126

TSS (mg/l) vs Adjusted Sludge TCDF (lbs/ton ADBSP)*10^8

Equation: $\log_{10}$(Adjusted Sludge TCDF) = 0.530 - 0.219 * $\log_{10}$(TSS)

R^2 = .004
Adjusted R^2 = .000
S.E. of Regression = 1.066

	Standard Error	t Statistic	p-Value
Constant	0.681	0.778	0.440
Independent	0.415	-0.527	0.600

TSS (mg/l) vs Adjusted Effluent TCDF (lbs/ton ADBSP)*10^8

Equation: $\log_{10}$(Adjusted Effluent TCDF) = -0.491 + 0.542 * $\log_{10}$(TSS)

R^2 = .048
Adjusted R^2 = .032
S.E. of Regression = 0.751

	Standard Error	t Statistic	p-Value
Constant	0.505	-0.972	0.335
Independent	0.307	1.765	0.082

FIGURE 6-6

EFFLUENT TCDD OUTPUT BY TREATMENT

TREATED KRAFT MILLS ONLY

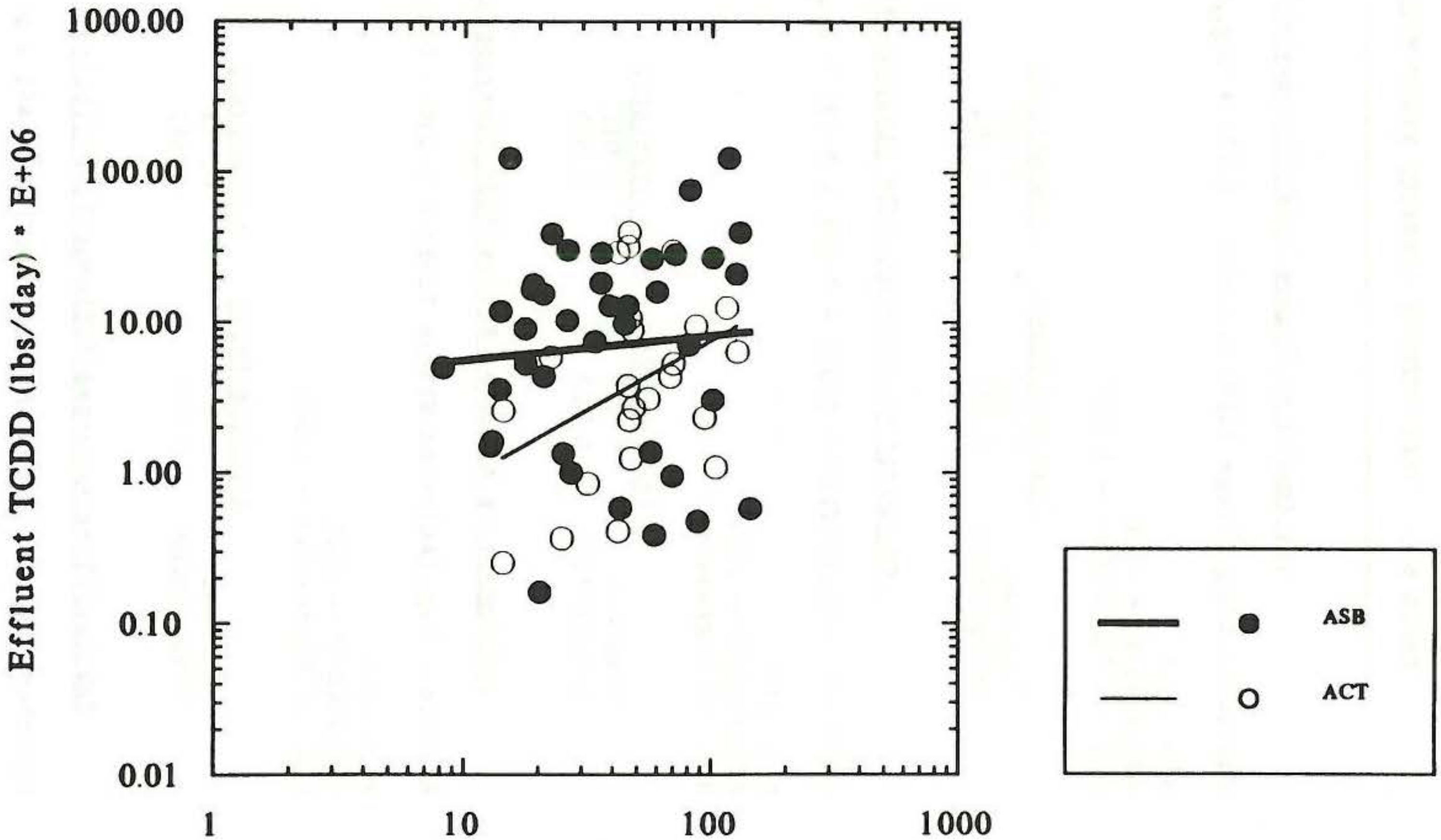


FIGURE 6-7

SLUDGE TCDD OUTPUT BY TREATMENT

TREATED KRAFT MILLS ONLY

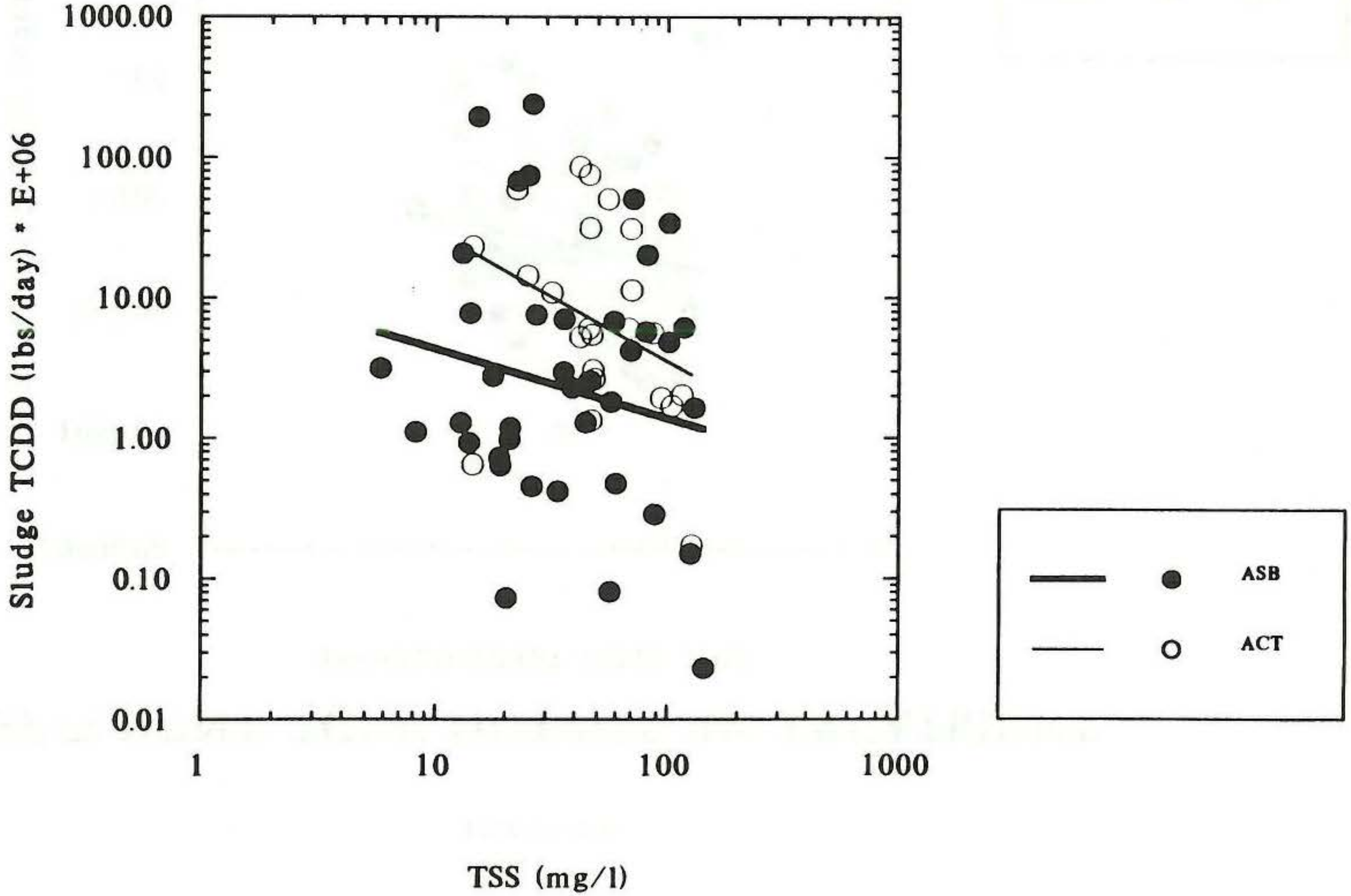


FIGURE 6-8

EFFLUENT TCDF OUTPUT BY TREATMENT

TREATED KRAFT MILLS ONLY

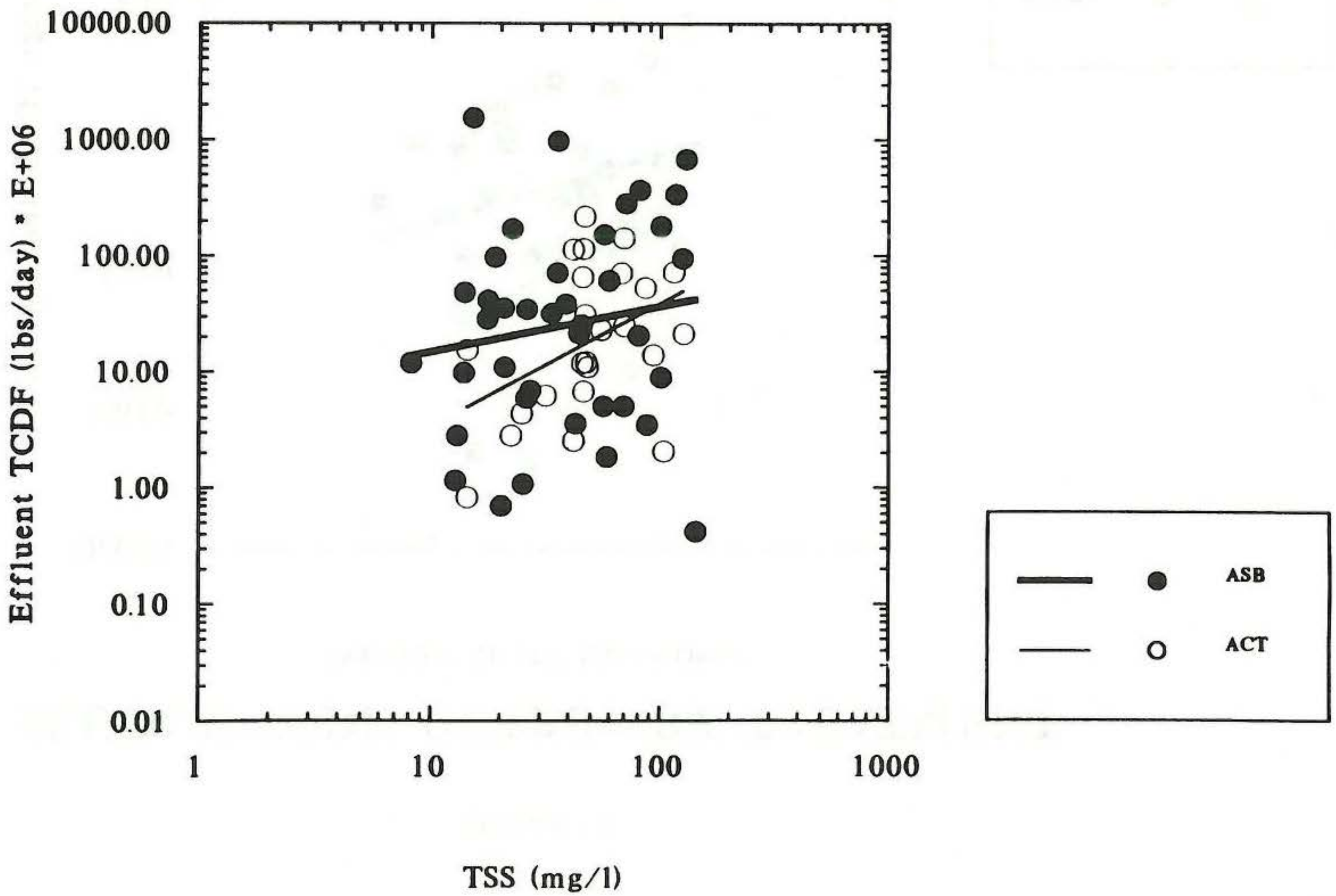


FIGURE 6-9

SLUDGE TCDF OUTPUT BY TREATMENT

TREATED KRAFT MILLS ONLY

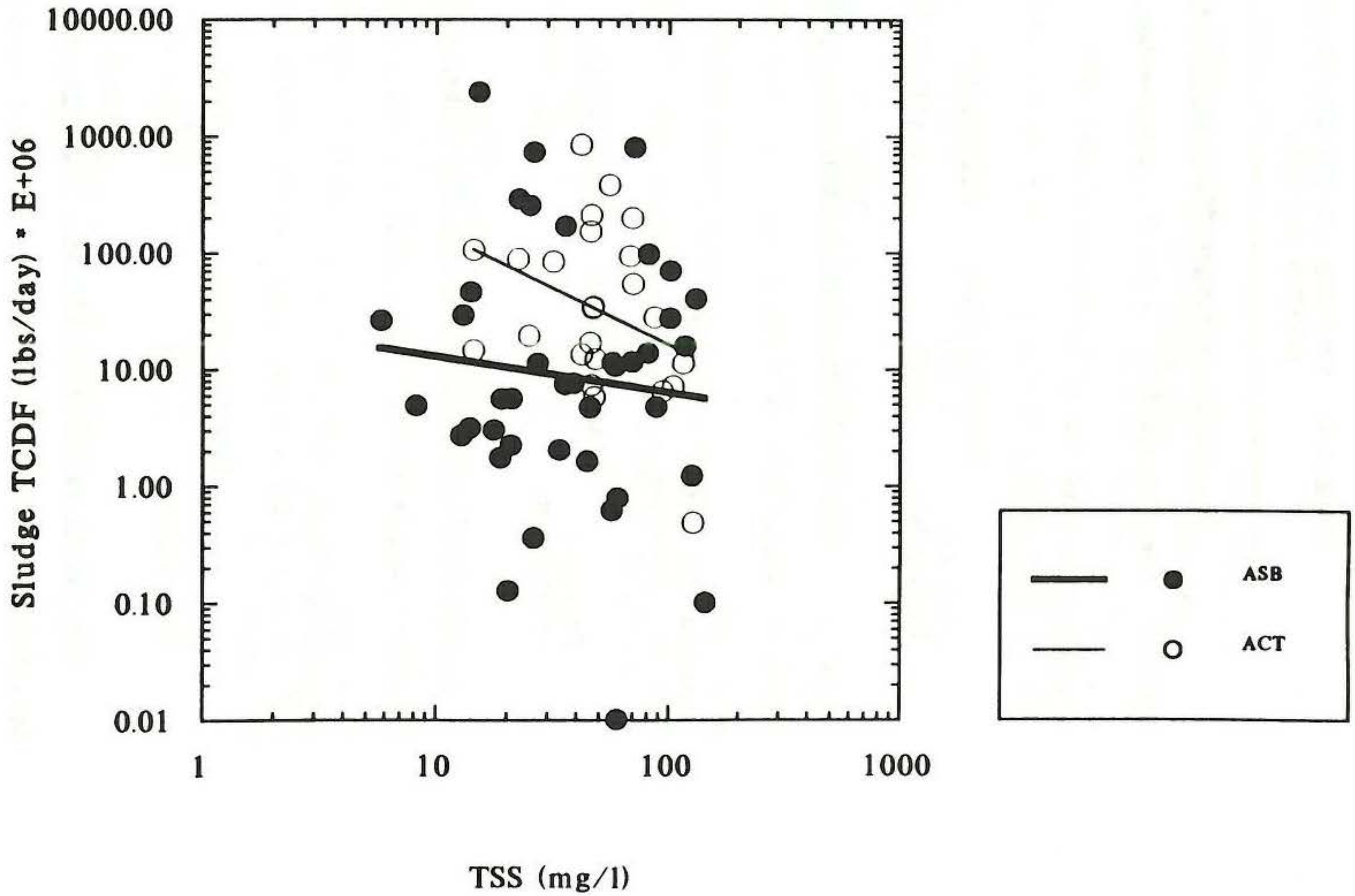


TABLE 6-6. TCDD EXPORTS FOR ASB TREATMENT KRAFT MILLS ONLY

TSS (mg/l) vs Sludge TCDD (lbs/day)*10^6

Equation: $\mathbf{Log_{10}(Sludge\ TCDD) = 1.128 - 0.495 * Log_{10}(TSS)}$

R^2 = .029
Adjusted R^2 = .004
S.E. of Regression = 1.023

	Standard Error	t Statistic	p-Value
Constant	0.738	1.527	0.135
Independent	0.462	-1.073	0.290

TSS (mg/l) vs Effluent TCDD (lbs/day)*10^6

Equation: $\mathbf{Log_{10}(Effluent\ TCDD) = 0.582 + 0.164 * Log_{10}(TSS)}$

R^2 = .006
Adjusted R^2 = .000
S.E. of Regression = 0.723

	Standard Error	t Statistic	p-Value
Constant	0.557	1.045	0.303
Independent	0.348	0.472	0.639

TSS (mg/l) vs Adjusted Sludge TCDD (lbs/ton ADBSP)*10^8

Equation: $\mathbf{Log_{10}(Adjusted\ Sludge\ TCDD) = 0.056 - 0.481 * Log_{10}(TSS)}$

R^2 = .026
Adjusted R^2 = .001
S.E. of Regression = 1.053

	Standard Error	t Statistic	p-Value
Constant	0.760	0.074	0.941
Independent	0.475	-1.012	0.318

TSS (mg/l) vs Adjusted Effluent TCDD (lbs/ton ADBSP)*10^8

Equation: $\mathbf{Log_{10}(Adjusted\ Effluent\ TCDD) = -0.447 + 0.169 * Log_{10}(TSS)}$

R^2 = .008
Adjusted R^2 = .000
S.E. of Regression = 0.654

	Standard Error	t Statistic	p-Value
Constant	0.504	-0.886	0.381
Independent	0.315	0.538	0.594

TABLE 6-7. TCDF EXPORTS FOR ASB TREATMENT KRAFT MILLS ONLY

TSS (mg/l) vs Sludge TCDF (lbs/day)*10^6

Equation: $\text{Log}_{10}(\text{Sludge TCDF}) = 1.425 - 0.312 * \text{Log}_{10}(\text{TSS})$

R^2 = .010
Adjusted R^2 = .000
S.E. of Regression = 1.106

	Standard Error	t Statistic	p-Value
Constant	0.798	1.785	0.082
Independent	0.499	-0.625	0.536

TSS (mg/l) vs Effluent TCDF (lbs/day)*10^6

Equation: $\text{Log}_{10}(\text{Effluent TCDF}) = 0.778 + 0.393 * \text{Log}_{10}(\text{TSS})$

R^2 = .022
Adjusted R^2 = .000
S.E. of Regression = 0.879

	Standard Error	t Statistic	p-Value
Constant	0.677	1.148	0.258
Independent	0.423	0.929	0.359

TSS (mg/l) vs Adjusted Sludge TCDF (lbs/ton ADBSP)*10^8

Equation: $\text{Log}_{10}(\text{Adjusted Sludge TCDF}) = 0.353 - 0.298 * \text{Log}_{10}(\text{TSS})$

R^2 = .008
Adjusted R^2 = .000
S.E. of Regression = 1.162

	Standard Error	t Statistic	p-Value
Constant	0.839	0.421	0.676
Independent	0.525	-0.567	0.574

TSS (mg/l) vs Adjusted Effluent TCDF (lbs/ton ADBSP)*10^8

Equation: $\text{Log}_{10}(\text{Adjusted Effluent TCDF}) = -0.251 + 0.398 * \text{Log}_{10}(\text{TSS})$

R^2 = .024
Adjusted R^2 = .000
S.E. of Regression = 0.857

	Standard Error	t Statistic	p-Value
Constant	0.661	-0.380	0.706
Independent	0.412	0.965	0.341

7. MODELING TCDD/TCDF FORMATION AS A FUNCTION OF MILL OPERATING PARAMETERS

Several steps were taken to investigate the effect of mill bleaching procedures upon 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) and 2,3,7,8-tetrachlorodibenzofuran (TCDF) formation. The goal of this section was to determine the strength of relationships between mass export rates of TCDD/TCDF and key chemical bleaching and extraction agents used at U.S. bleached pulp mills. Three dependent measures were used, including the total mass export rates of TCDD and TCDF generated by the combined vectors of pulp, sludge, and effluent (in lbs/ton Air-Dried Brownstock Pulp [ADBSP]); and the TCDD toxic equivalent export rate, which combines the TCDD total mass rate with one-tenth of the TCDF total mass rate.

Though the mass formation rates of TCDD/TCDF varied from bleach line to bleach line, as gauged by pulp sample analyses, effluents and sludges were not sampled at each line but rather at the "downstream" treatment facilities. Consequently, the chemical bleaching application rates for each bleach line were combined to form a mill average, the rates being weighted over different lines depending on the volume of pulp produced. As in the previous section, kraft and sulfite mills were treated separately in the analyses. Since the number of sulfite mills with usable data was quite small, only the analyses of kraft mills were included in this section.

The independent variables for which there were enough data to be of utility included the following: chemicals added during C-stage bleaching -- Chlorine (Cl_2), Chlorine Dioxide (ClO_2), Cl_2 Equivalent in C-Stage, and Percentage ClO_2 Substitution for Cl_2; chemicals added during other stages of bleaching or caustic removal -- Other stage ClO_2, Sodium Hypochlorite, Sodium Hydroxide, and Oxygen (O_2); and characterizing features of bleach line operation -- Kappa number, Final brightness, Cl_2 Line Equivalent, Cl_2 Multiple (Kappa Factor) in C-stage, Cl_2 Equivalent Multiple in C-stage, and Cl_2 Line Equivalent Multiple. Other variables had for the most part zero values and were not included in these analyses. They included Calcium Hypochlorite, Hydrogen Peroxide, Other Stage Cl_2, and other chemical agents which did not contain chlorine derivatives.

As was done in the analysis of total suspended solids, exploratory plots and regression analyses were performed only after the variables of interest were examined for distributional properties and skewness. If warranted, variables were transformed so that their distributions approximated normality as much as possible. (All figures and tables are located at the end of the text.)

Two of the independent variables -- O_2 and ClO_2 -- contained significant fractions of zero values (almost half of all kraft mills in the case of O_2). The analyses assumed an inherent difference between mills which, for instance, did not use <u>any</u> ClO_2 in bleaching and those mills which did. Two different distributions of the TCDD/TCDF mass export rates are presented for each of these variables, one for all cases of zero values in O_2 and ClO_2 and the other for cases when the two variables were positive (Tables 7-1 and 7-2).

7.1 REGRESSION ANALYSES

After analyzing and transforming variables where necessary, plots were made of each dependent measure versus each independent variable and then analyzed for trends. Figures 7-1 to 7-9 are representative of the most significant results. Each plot contains two important interpretive features: a least squares linear regression overlay, drawn over the actual range of data, and a 90 percent confidence band about the estimated regression line. The confidence band provides a visual indication of the degree to which, at any given point x_0 along the independent axis, the estimated mean of the dependent variate might be in error.

Mills in which the calculation of either TCDD or TCDF mass export rates was problematic (such as in cases of seasonal or no waste treatment) were not used in the scatterplots or regression analyses and were considered unreliable data for purposes of the report. Two mills discharged untreated effluents to the ocean, and another five mills had average wastewater retention spans of several months. At six mills, the reported concentration or flow data was incomplete, so TCDD/TCDF mass formation rates could not be calculated.

Corresponding to the above plots, equations of the regression lines and relevant summary statistics (including standard errors and R^2 values) are given in Tables 7-3 to 7-5. Since the regressions were performed on the transformed variables and not in the original units, the estimated relationships are not linear in the original variables. On the log-log scale, for example, a non-zero linear slope implies that the dependent variable tends to be proportional to a <u>power</u> of the independent variate.

The most immediate finding from the analysis is that each of the dependent variables exhibited significant variation at essentially every level of the various chemical application rates. Consequently, the proportion of variance explained by any of the regression equations was generally low (as given by R^2), indicating that the linear regressions were not very useful as predictive equations. In fact, specific predictions regarding output of TCDD/TCDF at mill Y when a certain level of chemical X was applied would probably have little meaning. The scatterplots were useful, however, to detect the presence or absence of non-zero trends in the estimated regression lines.

7.1.1 Effects of Chlorine Bleaching

Variables measuring the application of chlorine to brownstock pulps (Cl_2, Cl_2 Equivalent in C-Stage, Cl_2 Line Equivalent) were positively associated with the formation of TCDD/TCDF (Table 7-3). Hence, greater use of chlorine in bleaching was associated with higher formation rates of TCDD/TCDF. This result was consistent with previous evidence concerning the effect of chlorine bleaching on TCDD/TCDF formation in pulp mills (2); however, none of the estimated regression models involving these variables accounted for more than about 30 percent of the total variance in TCDD/TCDF mass export rates.

7.1.2 Effect of the Chlorine Multiple

Since more chlorine tends to be applied when the lignin content of the pulp is high, regressions were also estimated for variables involving ratios between the amount of chlorine applied and the Kappa number (as measured by the ratios Cl_2 Multiple, Cl_2 Equivalent Multiple, and Cl_2 Line Equivalent Multiple), the Kappa number being a useful index of lignin content in brownstock pulps. Table 7-4 provides the results for regressions on the Cl_2 Multiple, and again documents a generally significant positive relationship between formation of TCDD/TCDF in mass exports and the Cl_2 Multiple. Such a result implies that, on the average, even when lignin content was accounted for or "held constant," greater application of chlorine was mildly associated with higher formation of TCDD/TCDF. In this case, the association must be considered mild because the percentage of total variation accounted for by the estimated regression models never exceeded 18 percent.

7.1.3 Chlorine Dioxide Substitution

The substitution of ClO_2 for Cl_2 in the C-Stage of bleaching produced slight reductions in average TCDD/TCDF formation (Table 7-5), the regression trends being statistically significant at below the 2 percent level. However, the regression models accounted for at most 16 percent of the total variation in TCDD/TCDF mass exports, and since very few mills substituted ClO_2 for more than 30 percent of their chlorine usage, the regression trends cannot be reliably extrapolated to predict reductions of TCDD/TCDF formation at higher ClO_2 substitution rates. It was also seen in Table 7-1 that mills that did not use any ClO_2 exhibited tremendous variation in TCDD/TCDF mass exports. Hence, substitution of ClO_2 for Cl_2 was not by itself an adequate predictor of TCDD/TCDF reduction. Use of ClO_2 may help, however, to reduce TCDD/TCDF formation when considered in conjunction with other reduction strategies.

7.1.4 Use of Oxygen in Bleaching

Mills that use oxygen in the bleaching process exhibited a slight but statistically significant trend toward reduction of TCDD/TCDF with increased oxygen application. However, this trend was wholly attributable to those four kraft mills that used oxygen delignification methods at the time of the 104 Mill Study (Table 7-2). Furthermore, the same four mills also tended to have higher substitution rates of ClO_2 for Cl_2, so it cannot be determined whether the lower export rates of TCDD/TCDF observed at these mills were attributable to oxygen delignification, chlorine dioxide substitution, or some combination of both. Use of oxygen in other applications was not statistically correlated with TCDD/TCDF mass formation.

7.1.5 Differences in Wood Types

Due to limitations of the study design, softwood and hardwood bleach lines could not be systematically analyzed for differences in TCDD/TCDF mass formation. However, it was observed that greater amounts of chlorine were generally applied to softwood pulps than hardwood pulps per ton of pulp processed, and that the average Kappa numbers of softwood pulps were typically much higher than the Kappa numbers of hardwood pulps (Figures 7-10 and 7-11). Both of these observations were consistent with known differences in the bleaching practices of softwood versus hardwood pulps.

7.2 SUMMARY

To summarize, the most consistently significant independent variables were those involving chlorine application in the C-stage of bleaching: Cl_2 and Cl_2 Equivalent. Variables measuring the chlorine multiple (also known as the Kappa factor) were also positively associated with TCDD/TCDF formation, though the correlations were weaker. Substitution of chlorine dioxide for Cl_2 was associated with slight reductions in TCDD/TCDF formation. However, since very few mills reported ClO_2 substitution rates of more than 30 percent at the time of the study, the effect of higher chlorine dioxide substitution rates could not be gauged with any precision.

Barring more detailed information on chemical usage patterns and mill process characteristics, the data at hand preclude the fitting of very precise predictive models. While other variables might significantly impact the formation of 2378-TCDD/TCDF, in the 104 Mill Study only those measuring chlorine application rates were consistently linked to TCDD/TCDF formation at pulp mills.

TABLE 7-1. SUMMARY STATISTICS: BREAKDOWN BY ClO_2 USAGE

KRAFT MILLS ONLY

$ClO_2 = 0$	Adjusted Total TCDD	Adjusted Total TCDF	Adjusted TCDD Toxic Equivalent
N	27	27	27
Minimum	0.186	0.748	0.260
Maximum	16.337	299.613	43.026
Mean	4.110	27.940	6.904
Standard Dev.	4.260	61.417	9.433
Median	2.433	8.228	3.256

$ClO_2 > 0$	Adjusted Total TCDD	Adjusted Total TCDF	Adjusted TCDD Toxic Equivalent
N	52	52	52
Minimum	0.066	0.147	0.081
Maximum	30.556	953.875	118.722
Mean	5.331	59.818	11.313
Standard Dev.	6.152	149.441	19.996
Median	3.437	16.088	4.963

Adjusted Total - lbs/ton ADBSP * 10^8
Adjusted TCDD Toxic Equivalent - lbs/ton ADBSP * 10^8

TABLE 7-2. SUMMARY STATISTICS: BREAKDOWN BY O_2 USAGE

KRAFT MILLS ONLY

$O_2 = 0$	Adjusted Total TCDD	Adjusted Total TCDF	Adjusted TCDD Toxic Equivalent
N	34	34	34
Minimum	0.117	0.363	0.153
Maximum	13.065	299.613	43.026
Mean	3.764	27.054	6.469
Standard Dev.	3.603	55.415	8.492
Median	2.068	7.946	2.807

$O_2 > 0$ Extraction	Adjusted Total TCDD	Adjusted Total TCDF	Adjusted TCDD Toxic Equivalent
N	43	43	43
Minimum	0.124	0.450	0.283
Maximum	30.556	953.875	118.722
Mean	6.028	68.447	12.872
Standard Dev.	6.659	163.044	21.668
Median	3.589	15.778	5.153

$O_2 > 0$ Delignification	Adjusted Total TCDD	Adjusted Total TCDF	Adjusted TCDD Toxic Equivalent
N	2	2	2
Minimum	0.066	0.147	0.081
Maximum	0.960	1.747	1.135
Mean	0.513	0.947	0.608
Standard Dev.	0.632	1.131	0.745
Median	0.513	0.947	0.608

Adjusted Total - lbs/ton ADBSP * 10^8
Adjusted TCDD Toxic Equivalent - lbs/ton ADBSP * 10^8

FIGURE 7-1

Cl2 vs. ADJUSTED TOTAL TCDD

KRAFT MILLS ONLY

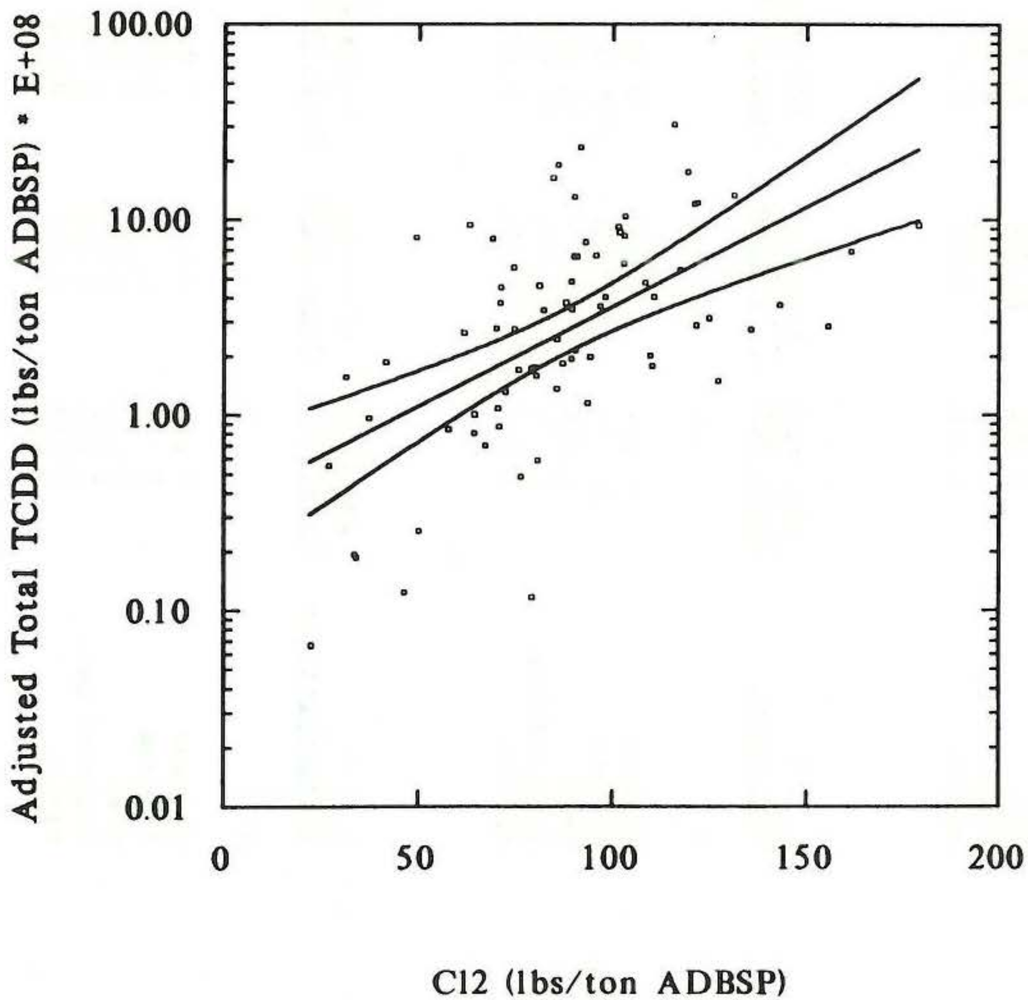


FIGURE 7-2

C12 vs. ADJUSTED TOTAL TCDF

KRAFT MILLS ONLY

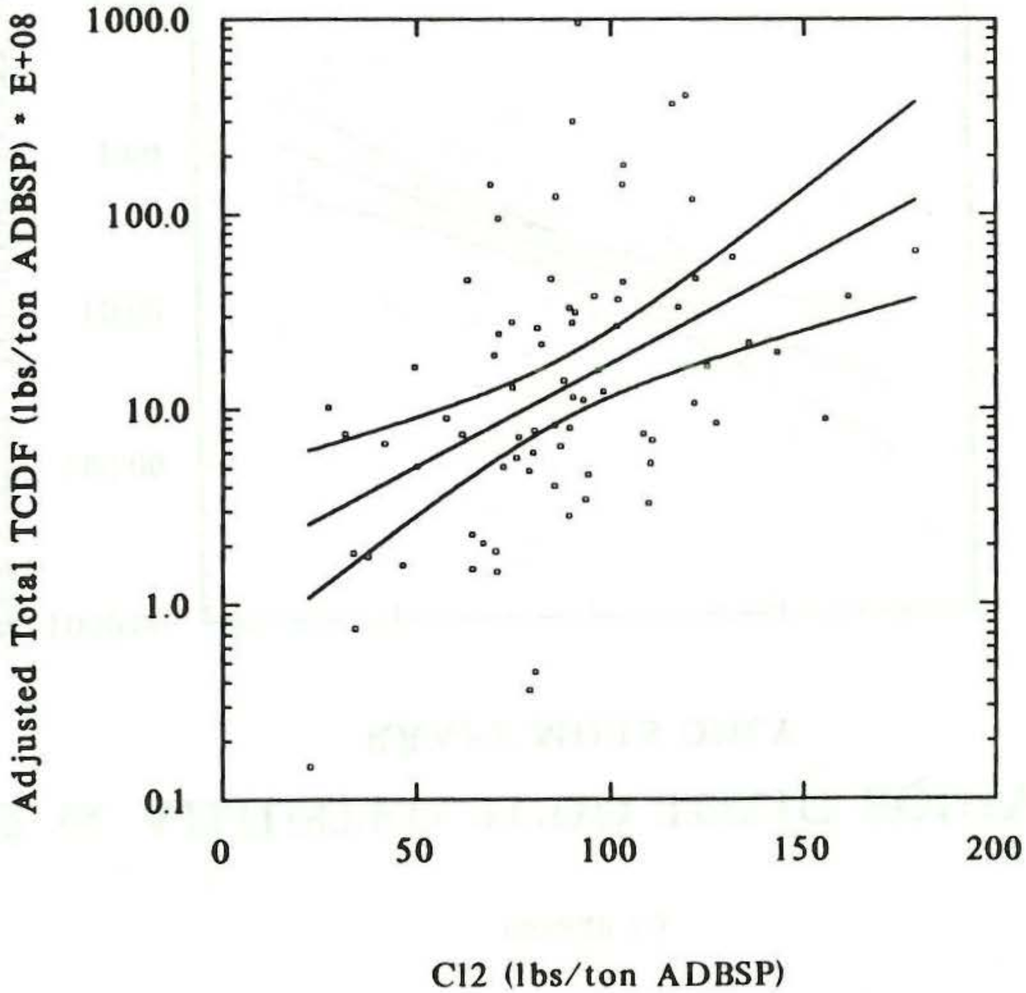


FIGURE 7-3

Cl2 vs. ADJUSTED TCDD TOXIC EQUIVALENT

KRAFT MILLS ONLY

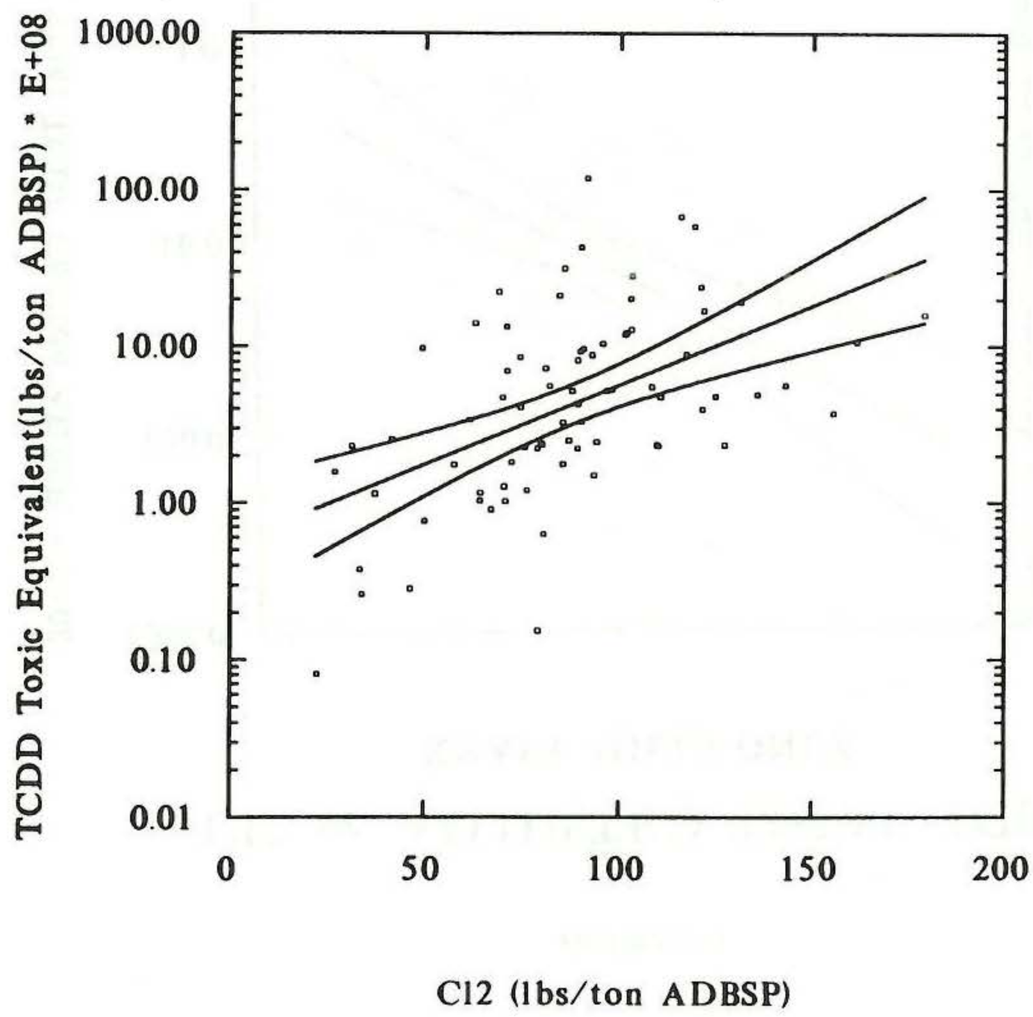


FIGURE 7-4

C12 MULTIPLE vs. ADJUSTED TOTAL TCDD

KRAFT MILLS ONLY

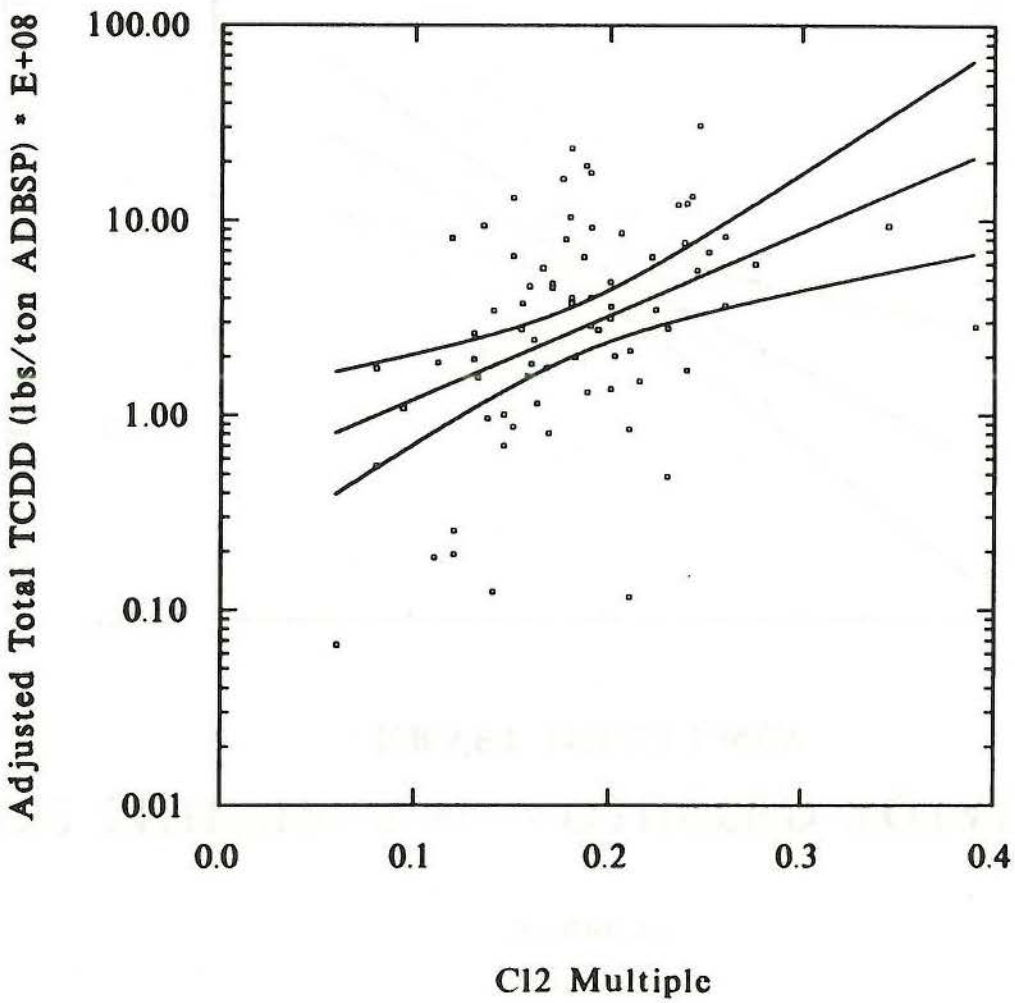


FIGURE 7-5

Cl2 MULTIPLE vs. ADJUSTED TOTAL TCDF

KRAFT MILLS ONLY

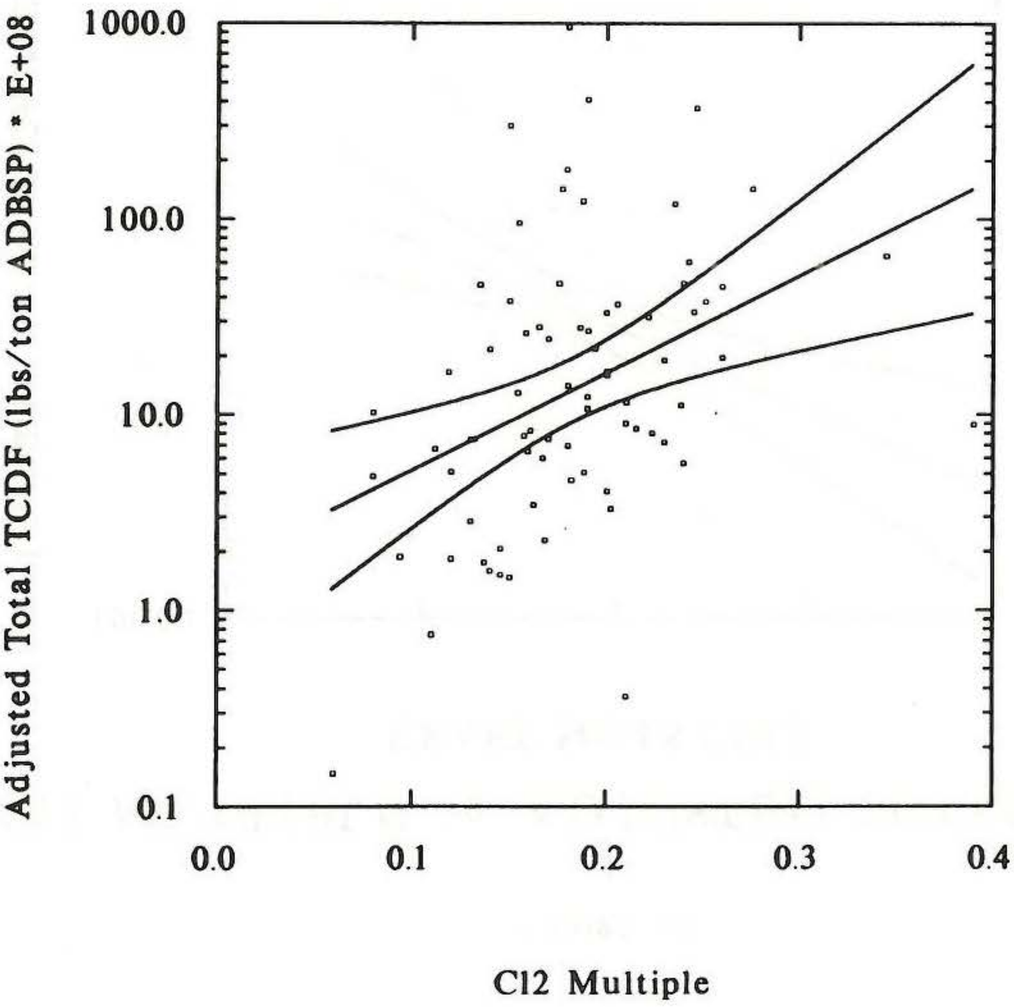


FIGURE 7-6

Cl2 MULTIPLE vs. ADJUSTED TCDD TOXIC EQUIVALENT

KRAFT MILLS ONLY

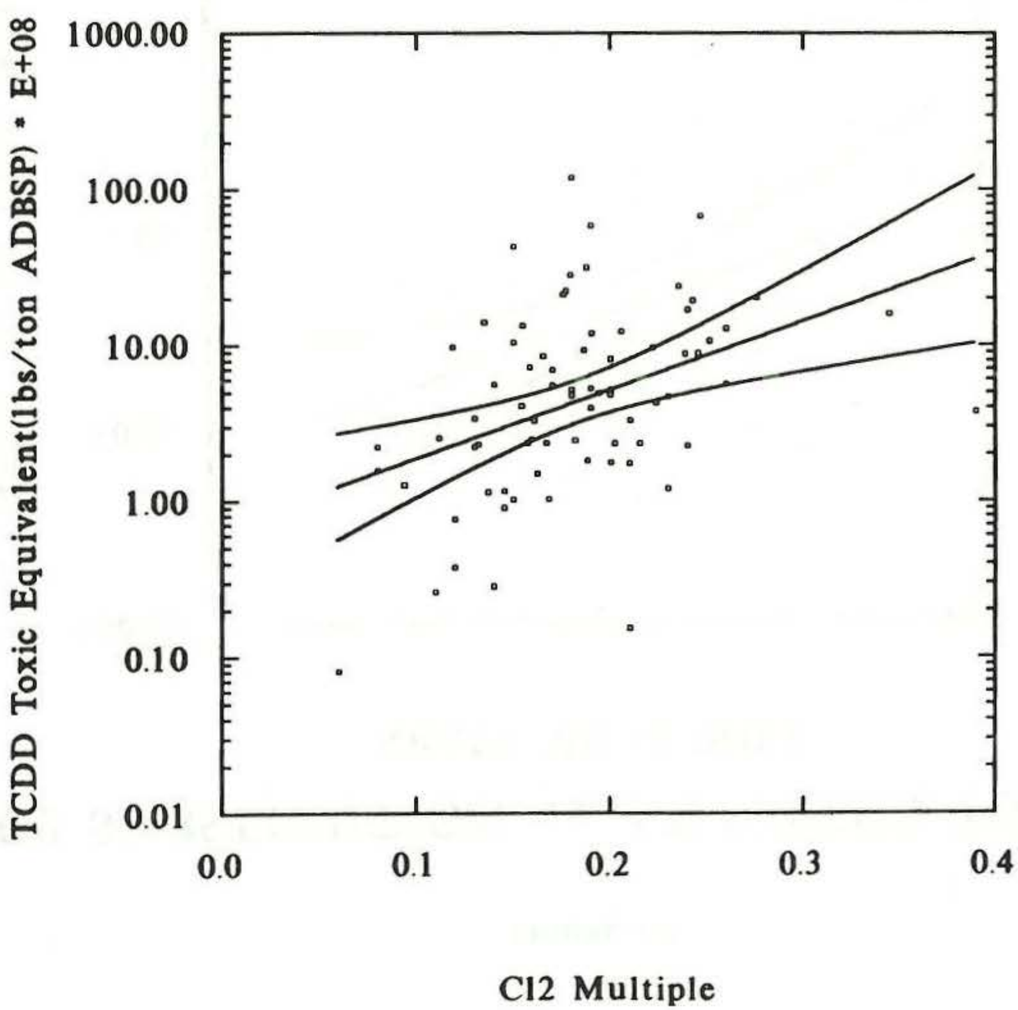


FIGURE 7-7

% ClO2 SUBSTITUTION vs. ADJUSTED TOTAL TCDD

KRAFT MILLS ONLY

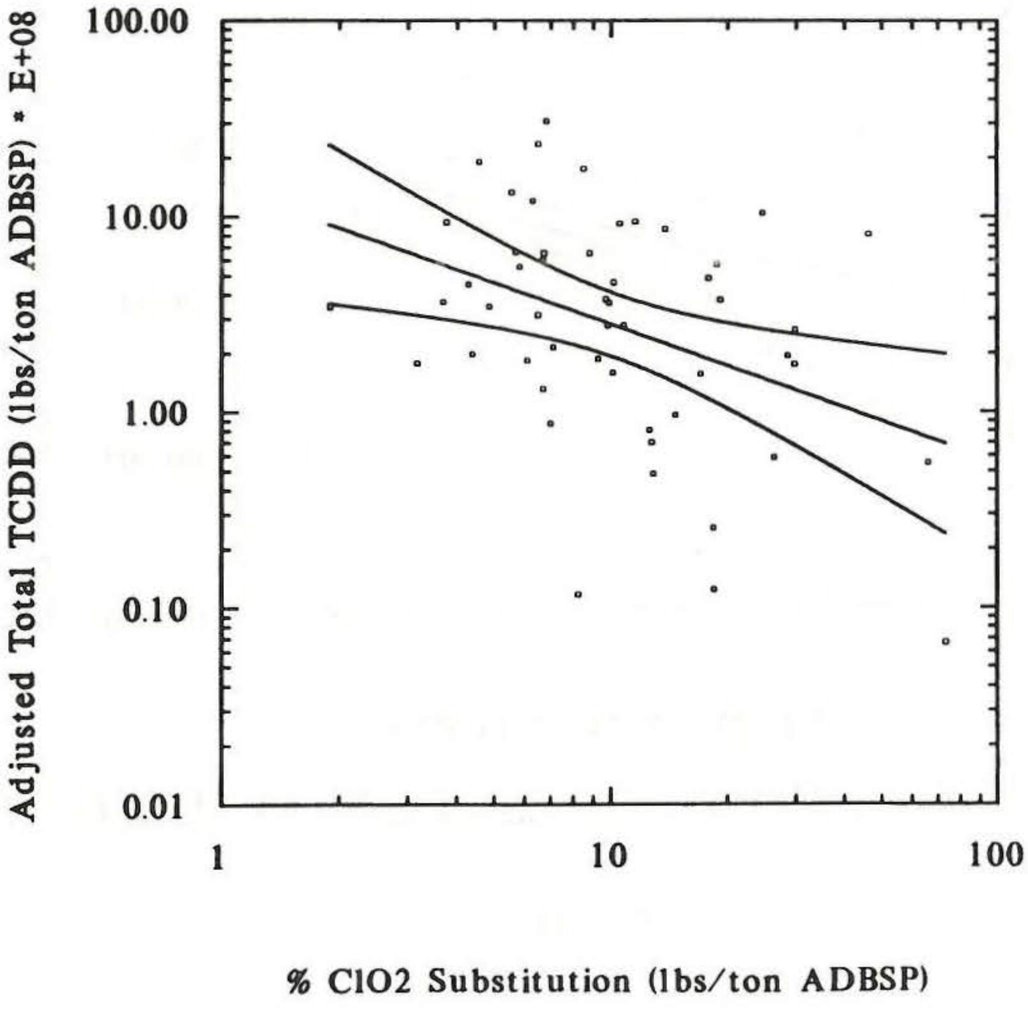


FIGURE 7-8

% ClO2 SUBSTITUTION vs. ADJUSTED TOTAL TCDF

KRAFT MILLS ONLY

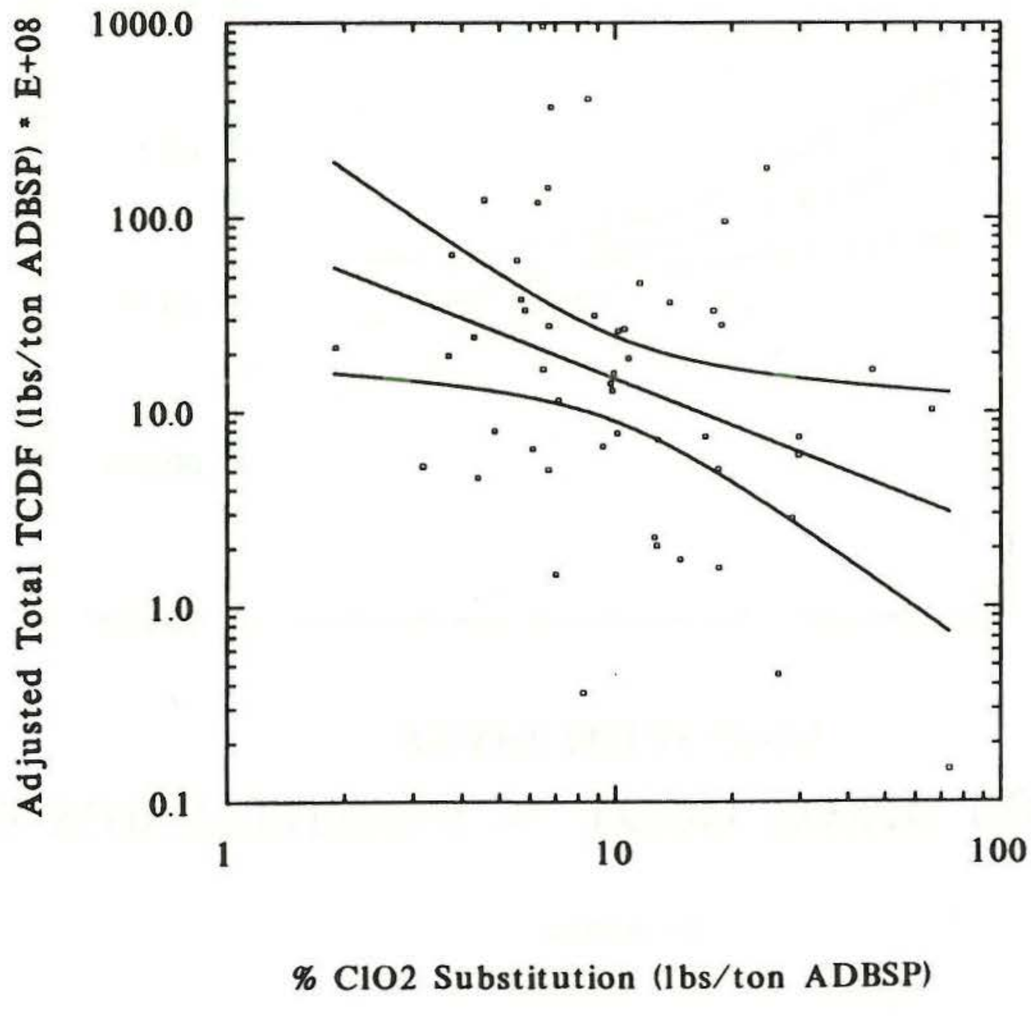
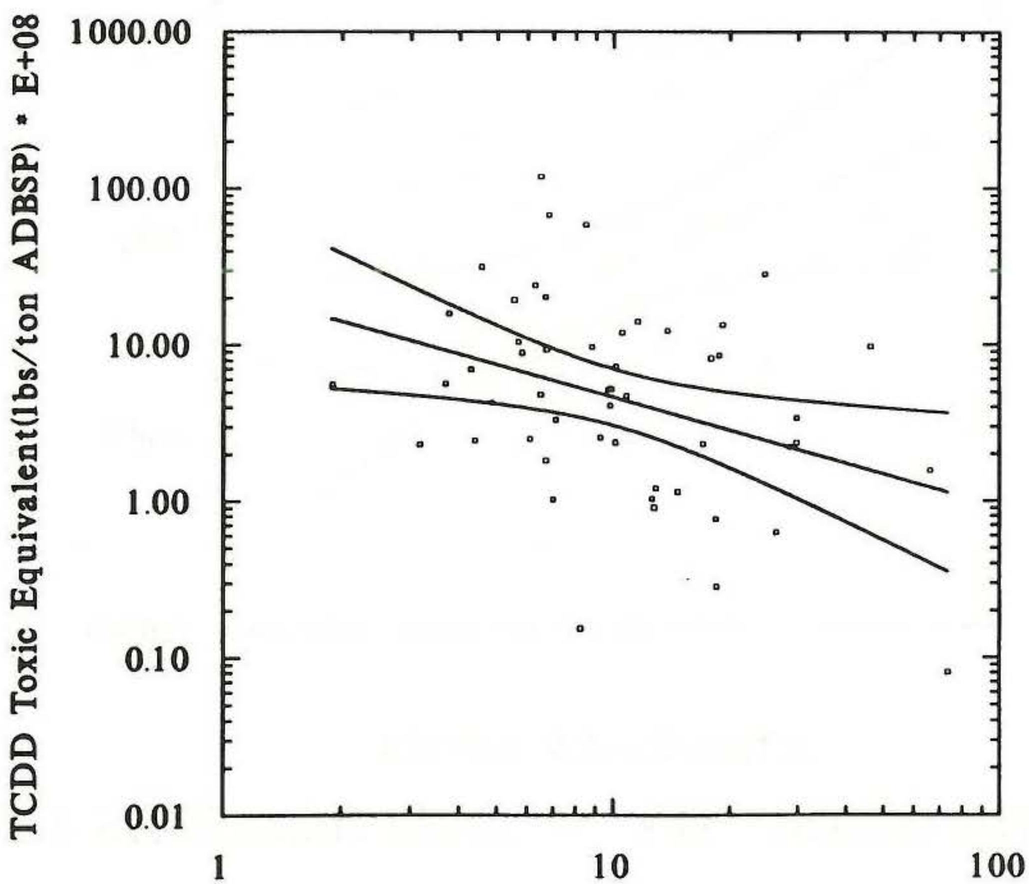


FIGURE 7-9

ClO2 SUBSTITUTION vs. TCDD TOXIC EQUIVALENT

KRAFT MILLS ONLY



% ClO2 Substitution (lbs/ton ADBSP)

TABLE 7-3. REGRESSIONS OF CHLORINE USAGE (KRAFT MILLS ONLY)

Cl_2 vs. Adjusted Total TCDD (lbs/ton ADBSP)*10^8

Equation: $\mathrm{Log}_{10}(\mathrm{Total\ TCDD}) = -0.462 + 0.010 * Cl_2$

R2 = .317
Adjusted R^2 = .308
S.E. of Regression = 0.461

	Standard Error	t Statistic	p-Value
Constant	0.160	-2.890	0.005
Independent	0.002	5.902	0.000

Cl_2 vs. Adjusted Total TCDF (lbs/ton ADBSP)*10^8

Equation: $\mathrm{Log}_{10}(\mathrm{Total\ TCDF}) = 0.179 + 0.011 * Cl_2$

R2 = .206
Adjusted R^2 = .195
S.E. of Regression = 0.641

	Standard Error	t Statistic	p-Value
Constant	0.223	0.804	0.424
Independent	0.002	4.405	0.000

Cl_2 vs. Adjusted TCDD Toxic Equivalent (lbs/ton ADBSP)*10^8

Equation: $\mathrm{Log}_{10}(\mathrm{TCDD\ Toxic\ Equivalent}) = -0.262 + 0.010 * Cl_2$

R2 = .271
Adjusted R^2 = .261
S.E. of Regression = 0.514

	Standard Error	t Statistic	p-Value
Constant	0.178	-1.466	0.147
Independent	0.002	5.275	0.000

TABLE 7-4. REGRESSIONS OF CHLORINE MULTIPLE (KRAFT MILLS ONLY)

Cl_2 Multiple vs. Adjusted Total TCDD (lbs/ton ADBSP)*10^8

Equation: $\log_{10}$(Total TCDD) = -0.343 + 4.280 * Cl_2 Multiple

R^2 = .181
Adjusted R^2 = .170
S.E. of Regression = 0.506

	Standard Error	t Statistic	p-Value
Constant	0.203	-1.685	0.096
Independent	1.064	4.023	0.000

Cl_2 Multiple vs. Adjusted Total TCDF (lbs/ton ADBSP)*10^8

Equation: $\log_{10}$(Total TCDF) = 0.221 + 4.968 * Cl_2 Multiple

R^2 = .153
Adjusted R^2 = .141
S.E. of Regression = 0.651

	Standard Error	t Statistic	p-Value
Constant	0.262	0.843	0.402
Independent	1.369	3.629	0.001

Cl_2 Multiple vs. TCDD Toxic Equivalent (lbs/ton ADBSP)*10^8

Equation: $\log_{10}$(TCDD Tox. Eq.) = -0.166 + 4.413 * Cl_2 Multiple

R^2 = .167
Adjusted R^2 = .156
S.E. of Regression = 0.549

	Standard Error	t Statistic	p-Value
Constant	0.220	-0.752	0.455
Independent	1.154	3.825	0.000

TABLE 7-5. REGRESSIONS OF ClO_2 SUBSTITUTION (KRAFT MILLS ONLY)

ClO_2 Substitution vs. Adjusted Total TCDD (lbs/ton ADBSP)*10^8

Equation: $Log_{10}(\text{Total TCDD}) = 1.157 - 0.708 * Log_{10}(\%\ ClO_2\ \text{Sub.})$

$R^2 = .160$
Adjusted $R^2 = .143$
S.E. of Regression = 0.538

	Standard Error	t Statistic	p-Value
Constant	0.244	4.732	0.000
Independent	0.230	-3.081	0.003

ClO_2 Substitution vs. Adjusted Total TCDF (lbs/ton ADBSP)*10^8

Equation: $Log_{10}(\text{Total TCDF}) = 1.961 - 0.792 * Log_{10}(\%\ ClO_2\ \text{Sub.})$

$R^2 = .117$
Adjusted $R^2 = .100$
S.E. of Regression = 0.718

	Standard Error	t Statistic	p-Value
Constant	0.326	6.009	0.000
Independent	0.307	-2.579	0.013

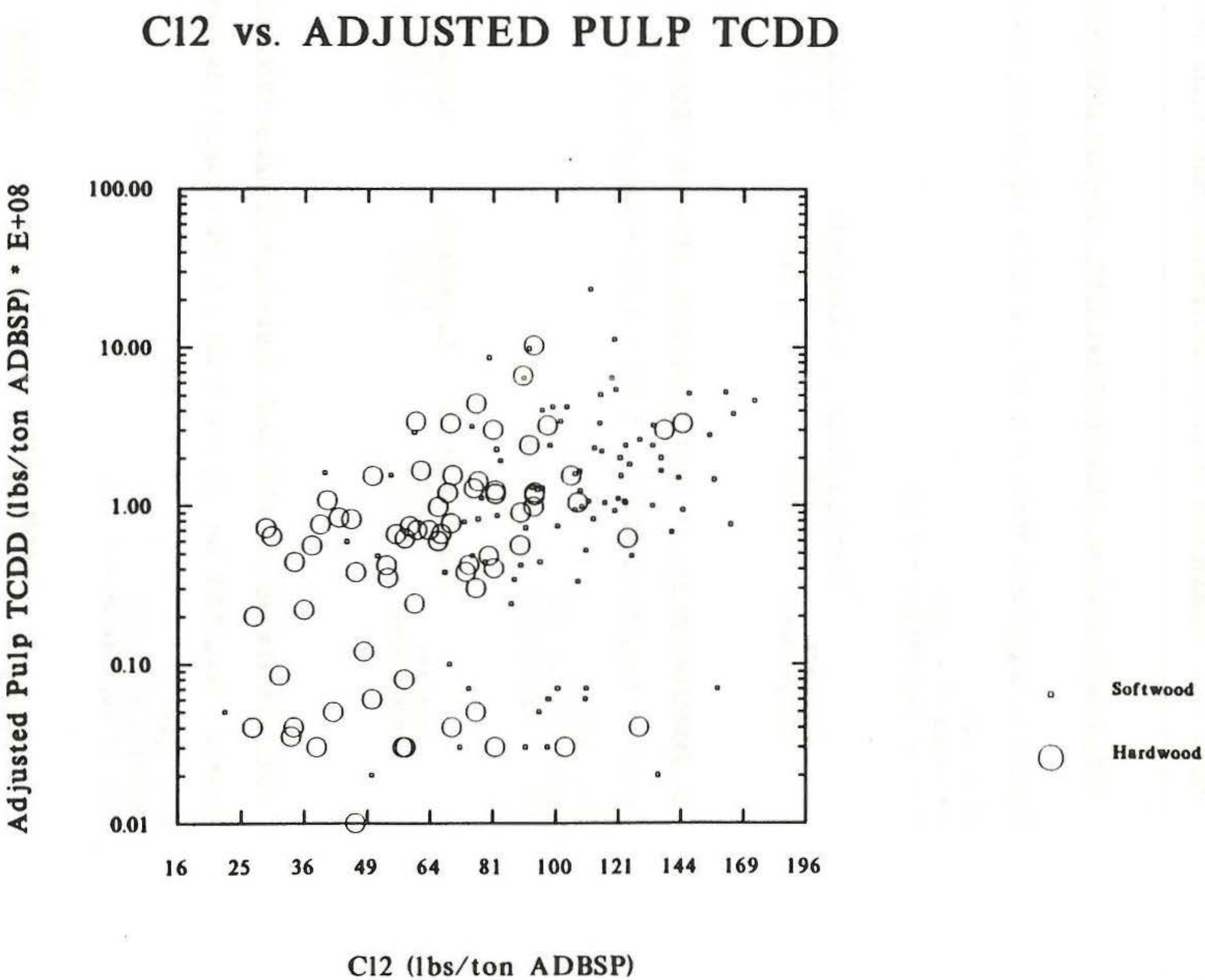
ClO_2 Substitution vs. TCDD Toxic Equivalent (lbs/ton ADBSP)*10^8

Equation: $Log_{10}(\text{TCDD Tox. Eq.}) = 1.362 - 0.700 * Log_{10}(\%\ ClO_2\ \text{Sub.})$

$R^2 = .133$
Adjusted $R^2 = .115$
S.E. of Regression = 0.593

	Standard Error	t Statistic	p-Value
Constant	0.269	5.057	0.000
Independent	0.253	-2.764	0.008

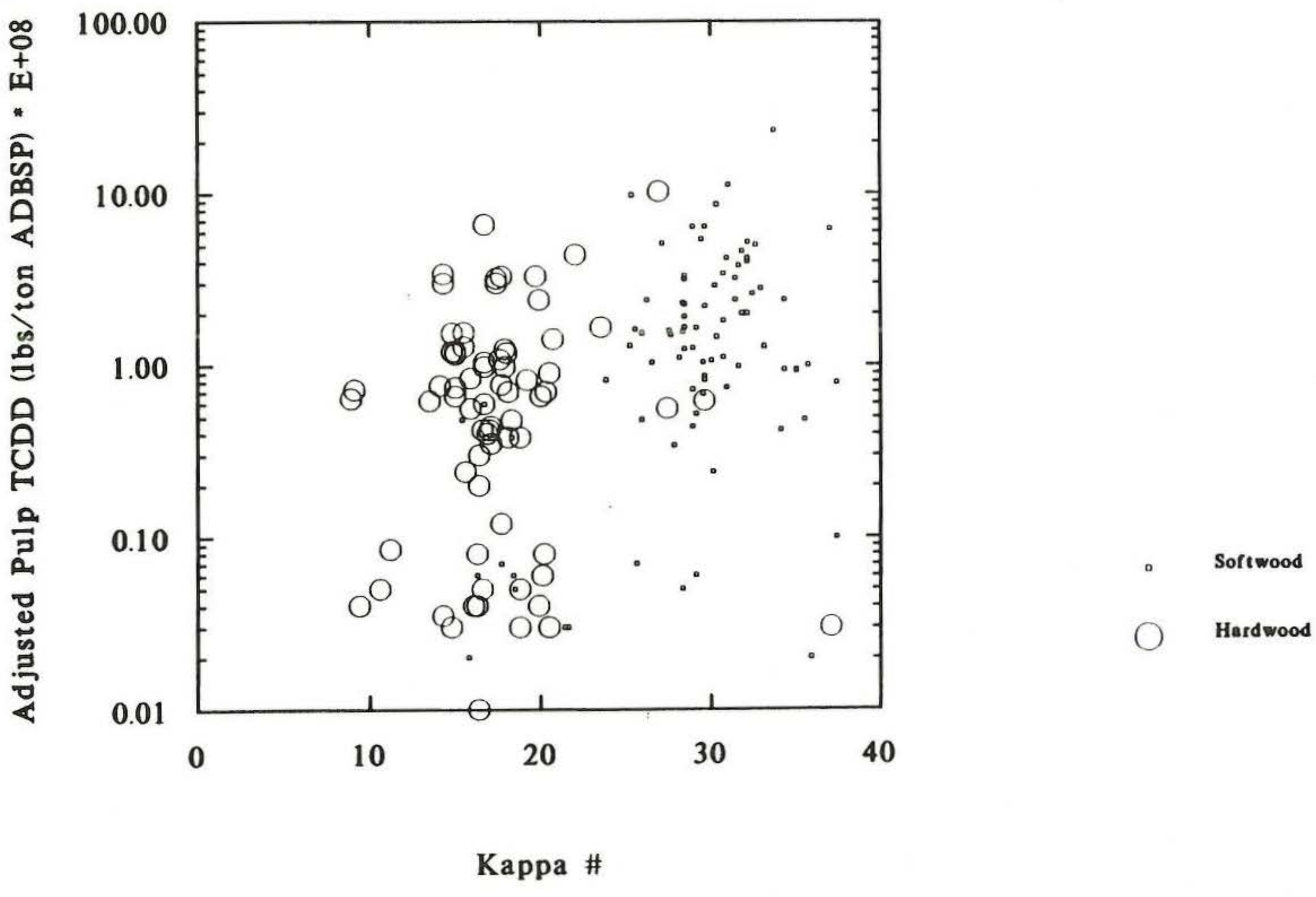
FIGURE 7-10



C12 vs. ADJUSTED PULP TCDD
Adjusted Pulp TCDD (lbs/ton ADBSP) * E+08
100.00
10.00
1.00
0.10
0.01
16
25
36
49
64
81
100
121
144
169
196
C12 (lbs/ton ADBSP)
Softwood
Hardwood

FIGURE 7-11

KAPPA # vs. ADJUSTED PULP TCDD



APPENDIX A: DATA LISTINGS

A-1. 104 MILL DATA LISTING

Company	City	State	Pulping Process	Treatment	TSS (mg/l)
Gaylord Container Corp.	Antioch	CA	Kraft	ACT	68.00
Wilamette Industries	Hawesville	KY	Kraft	ASB	143.80
Alaska Pulp Co.	Sitka	AK	Sulfite	ACT	75.00
Badger Paper Mills, Inc.	Peshtigo	WI	Sulfite	ACT	125.15
Kimberly-Clark Corp.	Coosa Pines	AL	Kraft	ASB	18.80
Lincoln Pulp and Paper	Lincoln	ME	Kraft	ACT	48.40
Wausau Paper Mills Co.	Brokaw	WI	Sulfite	ACT	39.20
Gilman Paper Co.	St. Marys	GA	Kraft	ASB	69.50
Gulf States Paper Corp.	Demopolis	AL	Kraft	ASB	80.80
Hammermill Paper Co.	Erie	PA	Kraft	POTW	203.10
Hammermill Paper Co.	Selma	AL	Kraft	ASB	60.00
International Paper Co.	Bastrop	LA	Kraft	ASB	81.50
International Paper Co.	Georgetown	SC	Kraft	ASB	117.00
International Paper Co.	Jay	ME	Kraft	ACT	.
International Paper Co.	Mobile	AL	Kraft	ASB	101.00
International Paper Co.	Moss Point	MS	Kraft	ASB	57.20
International Paper Co.	Natchez	MS	Kraft	ACT	115.00
International Paper Co.	Pine Bluff	AR	Kraft	ASB	71.00
International Paper Co.	Texarkana	TX	Kraft	ASB	5.80
International Paper Co.	Ticonderoga	NY	Kraft	ACT	55.50
ITT-Rayonier, Inc.	Fernandina Beach	FL	Sulfite	ASB	200.40
ITT-Rayonier, Inc.	Hoquiam	WA	Sulfite	ACT	75.80
ITT-Rayonier, Inc.	Jesup	GA	Kraft	ASB	26.07
ITT-Rayonier, Inc.	Port Angeles	WA	Sulfite	ACT	273.00
James River Corp.	Berlin	NH	Kraft	ACT	47.00
James River Corp.	Camas	WA	K/S	ASB	78.60
James River Corp.	Clatskanie	OR	Kraft	ACT	.
James River Corp.	Green Bay	WI	Sulfite	POTW	177.15
James River Corp.	Old Town	ME	Kraft	ACT	127.00
James River Corp.	St. Francesville	LA	Kraft	ASB	35.60
James River Corp.	Butler	AL	Kraft	ASB	17.60
Leaf River Forest Products	New Augusta	MS	Kraft	ACT	46.00
Longview Fibre Co.	Longview	WA	Kraft	ACT	47.20
Ketchikan Pulp & Paper Co.	Ketchikan	AK	Sulfite	ACT	243.60
Louisiana Pacific Corp.	Samoa	CA	Kraft	NONE	96.70
Mead Corporation	Chillicothe	OH	Kraft	ACT/ASB	.
Mead Corporation	Escanaba	MI	Kraft	ACT	14.40
Mead Corporation	Kingsport	TN	Soda	ASB	88.00
Nekoosa Papers, Inc.	Ashdown	AR	Kraft	ASB	20.80
Nekoosa Papers, Inc.	Nekoosa	WI	Kraft	ACT	36.00
Nekoosa Papers, Inc.	Port Edwards	WI	Sulfite	ACT	.
Penntech Papers, Inc.	Johnsonburg	PA	Kraft	ASB	42.85
Pope & Talbot, Inc.	Halsey	OR	Kraft	ASB	13.90
Potlatch Corp.	Cloquet	MN	Kraft	POTW	129.00
Potlatch Corp.	Lewiston	ID	Kraft	ASB	125.60
Potlatch Corp.	McGhee	AR	Kraft	ASB	21.00
Alabama River Pulp	Claiborne	AL	Kraft	ACT	86.50
Appleton Papers, Inc.	Roaring Springs	PA	Kraft	ACT	14.40
Boise Cascade Corp.	Jackson	AL	Kraft	ASB	19.00
Boise Cascade Corp.	Deridder	LA	Kraft	ASB	58.70
Boise Cascade Corp.	St. Helens	OR	Kraft	POTW	59.00
Boise Cascade Corp.	Rumford	ME	Kraft	ACT	69.60
Boise Cascade Corp.	Wallula	WA	Kraft	ASB	.
Boise Cascade Corp.	International Falls	MN	Kraft	ACT	.
Bowater Corp.	Catawba	SC	Kraft	ASB	13.00
Bowater Corp.	Calhoun	TN	Kraft	ASB	25.20
Brunswick Pulp and Paper	Brunswick	GA	Kraft	ASB	45.60
Buckeye Cellulose	Perry	FL	Kraft	ASB	38.80
Buckeye Cellulose	Oglethorpe	GA	Kraft	ASB	20.30
Champion International	Lufkin	TX	Kraft	ACT	.
Champion International	Courtland	AL	Kraft	ASB	22.60
Champion International	Quinnesec	MI	Kraft	ACT	31.70
Champion International	Cantonment	FL	Kraft	ASB	27.20
Champion International	Houston	TX	Kraft	ACT	24.90
Champion International	Canton	NC	Kraft	ACT	22.40
Chesapeake Corp.	West Point	VA	Kraft	ACT	93.80
Container Corp. of America	Brewton	AL	Kraft	ASB	12.80
Pentair, Inc.	Park Falls	WI	Sulfite	ACT	98.30
Federal Paper Board Co.	Augusta	GA	Kraft	ASB	101.20

A-1. 104 MILL DATA LISTING (CONTINUED)

Company	City	State	Pulping Process	Treatment	TSS (mg/l)
Federal Paper Board Co.	Riegelwood	NC	Kraft	ASB	44.40
Finch Pruyn & Co., Inc.	Glens Falls	NY	Sulfite	ACT	26.80
Georgia-Pacific Corp.	Bellingham	WA	Sulfite	ASB	.
Georgia-Pacific Corp.	Crosset	AR	Kraft	ACT	41.80
Georgia-Pacific Corp.	Palatka	FL	Kraft	ASB	8.20
Georgia-Pacific Corp.	Woodland	ME	Kraft	ASB	56.80
Georgia-Pacific Corp.	Zachary	LA	Kraft	ASB	130.00
P.H. Glatfelter Co.	Spring Grove	PA	Kraft	ACT	42.00
Proctor & Gamble Co.	Mehoopany	PA	Sulfite	ACT	127.60
Scott Paper Co.	Everett	WA	Sulfite	ACT	30.19
Scott Paper Co.	Mobile	AL	Kraft	ACT	47.70
Scott Paper Co.	Hinckley	ME	Kraft	ACT	70.00
Scott Paper Co.	Muskegon	MI	Kraft	POTW	.
Scott Paper Co.	Westbrook	ME	Kraft	ACT	104.20
Simpson Paper Co.	Anderson	CA	Kraft	ASB	35.80
Simpson Paper Co.	Fairhaven	CA	Kraft	NONE	137.00
Simpson Paper Co.	Pasadena	TX	Kraft	ACT	880.00
Simpson Paper Co.	Tacoma	WA	Kraft	ACT	46.40
St. Joe Paper Co.	Port St. Joe	FL	Kraft	POTW	.
Stone Container Corp.	Missoula	MT	Kraft	ASB	.
Stone Container Corp.	Panama City	FL	Kraft	POTW	108.80
Stone Container Corp.	Snowflake	AZ	Kraft	POND	.
Temple-Eastex, Inc.	Evadale	TX	Kraft	ASB	26.20
Union Camp Corp.	Eastover	SC	Kraft	ASB	1.80
Union Camp Corp.	Franklin	VA	Kraft	ASB	60.00
Westvaco Corp.	Covington	VA	Kraft	ACT	46.30
Westvaco Corp.	Luke	MD	Kraft	POTW	56.80
Westvaco Corp.	Wickliffe	KY	Kraft	ASB	33.70
Weyerhauser Co.	Cosmopolis	WA	Sulfite	ACT/ASB	121.40
Weyerhauser Co.	Everett	WA	Kraft	ASB	17.70
Weyerhauser Co.	Longview	WA	Kraft	ACT	45.80
Weyerhauser Co.	New Bern	NC	Kraft	ASB	14.00
Weyerhauser Co.	Plymouth	NC	Kraft	ASB	15.20
Weyerhauser Co.	Rothchild	WI	Sulfite	ACT	27.20

A-2. TCDD/TCDF CONCENTRATION DATA

MATRIX-PULP (ppt)
HARDWOOD

Company	City	State	Sample ID	Sample Date	TCDD	TCDD Date	TCDF	TCDF Date	Lab
Wilamette Industries	Hawesville	KY	M63PAC	10/28/88	0.30	12/30/88	1.10	12/30/88	WSU
Wilamette Industries	Hawesville	KY	M63PBC	10/28/88	0.50	12/30/88	1.90	12/30/88	WSU
Badger Paper Mills, Inc.	Peshtigo	WI	M46PC	07/22/88	4.40	12/16/88	323.00	12/16/88	WSU
Kimberly-Clark Corp.	Coosa Pines	AL	M36PAC	08/26/88	0.30	12/02/88	1.00	12/02/88	WSU
Wausau Paper Mills Co.	Brokaw	WI	M54PC	07/22/88	0.40	12/09/88	9.90	12/09/88	WSU
Gilman Paper Co.	St. Marys	GA	M55PAC	09/02/88	2.80	12/09/88	6.80	12/09/88	WSU
Hammermill Paper Co.	Erie	PA	M103PC	06/19/88	6.40	11/11/88	22.00	11/11/88	WSU
Hammermill Paper Co.	Selma	AL	M88PAC	06/26/88	2.10	12/16/88	21.00	12/16/88	WSU
International Paper Co.	Bastrop	LA	M85PAC	06/20/88	5.10	12/16/88	22.00	12/16/88	WSU
International Paper Co.	Bastrop	LA	M85PAC1	06/20/88	5.70	12/16/88	23.00	12/16/88	WSU
International Paper Co.	Georgetown	SC	M70PBC	07/16/88	1.90	12/09/88	7.70	12/09/88	WSU
International Paper Co.	Jay	ME	RG186367	.	55.70	04/21/87	181.00	04/21/87	WSU
International Paper Co.	Jay	ME	RG186367	.	46.70	08/19/87	183.00	08/19/87	WSU
International Paper Co.	Mobile	AL	M71PBC	10/24/88	3.50	12/30/88	14.00	12/30/88	WSU
International Paper Co.	Moss Point	MS	M34PBC	06/07/88	15.00	11/11/88	105.00	11/11/88	WSU
International Paper Co.	Natchez	MS	M97PBC	08/12/88	2.20	06/30/89	3.00	06/30/89	CAL
International Paper Co.	Natchez	MS	M97P11	08/12/88	3.60	11/03/88	15.00	11/03/88	CAL
International Paper Co.	Pine Bluff	AR	M51PAC	06/17/88	21.00	11/18/88	647.00	11/18/88	WSU
International Paper Co.	Pine Bluff	AR	M51PAC	06/17/88	23.00	11/18/88	661.00	11/18/88	WSU
International Paper Co.	Texarkana	TX	M99PAC	08/06/88	7.10	12/23/88	51.00	12/23/88	WSU
International Paper Co.	Ticonderoga	NY	M9PAC	06/24/88	16.00	11/04/88	103.00	11/04/88	WSU
International Paper Co.	Ticonderoga	NY	M9PAC	06/24/88	17.00	11/04/88	108.00	11/04/88	WSU
ITT-Rayonier, Inc.	Fernandina Beach	FL	M90PC	07/07/88	0.20	12/30/88	0.50	12/30/88	WSU
James River Corp.	Berlin	NH	M89PBC	08/19/88	3.30	11/04/88	41.00	11/04/88	WSU
James River Corp.	Camas	WA	M32PBC	.	0.30	11/04/88	0.90	11/04/88	WSU
James River Corp.	Green Bay	WI	M72PC	.	0.80	11/25/88	7.10	11/25/88	WSU
James River Corp.	Butler	AL	M96PAC	06/16/88	3.30	11/04/88	19.00	11/04/88	WSU
James River Corp.	Butler	AL	M96PCC	06/16/88	3.70	12/23/88	30.00	12/23/88	WSU
Leaf River Forest Products	New Augusta	MS	M35HPC60	02/27/88	3.80	04/19/89	7.70	04/19/89	CAL
Mead Corporation	Chillicothe	OH	DE026003	10/18/86	0.60	.	15.00	.	WSU
Mead Corporation	Escanaba	MI	MP105	12/15/87	18.00	03/09/88	68.00	03/09/88	CAL
Mead Corporation	Escanaba	MI	MP106	12/15/87	15.00	03/21/88	39.00	03/21/88	CAL
Mead Corporation	Kingsport	TN	M73PC	06/06/88	1.50	11/11/88	26.00	11/11/88	WSU
Nekoosa Papers, Inc.	Port Edwards	WI	M50PC	06/17/88	0.40	11/18/88	4.10	11/18/88	WSU
Nekoosa Papers, Inc.	Ashdown	AR	M20PAC	10/08/88	2.80	12/23/88	27.00	12/23/88	WSU
Penntech Papers, Inc.	Johnsonburg	PA	M57PC	08/01/88	3.10	12/09/88	38.00	12/09/88	WSU
Potlatch Corp.	Cloquet	MN	M38PC60	09/24/88	1.20	01/12/89	5.00	01/12/89	CAL
Potlatch Corp.	McGhee	AR	M18PBC	07/15/88	12.00	12/02/88	83.00	12/02/88	WSU
Alabama River Pulp	Claiborne	AL	M21PC	06/07/88	3.90	11/11/88	97.00	11/11/88	WSU
Alabama River Pulp	Claiborne	AL	M21PC1	06/07/88	3.80	11/11/88	98.00	11/11/88	WSU
Appleton Papers, Inc.	Roaring Springs	PA	M13PC40	06/26/88	1.00	11/03/88	21.00	11/03/88	CAL
Boise Cascade Corp.	Rumford	ME	M82PBC	06/02/88	17.00	11/11/88	111.00	11/11/88	WSU
Boise Cascade Corp.	International Falls	MN	DE020904	06/25/86	4.90	.	47.00	.	WSU
Boise Cascade Corp.	International Falls	MN	DE020905	06/25/86	3.00	.	50.00	.	WSU
Brunswick Pulp and Paper	Brunswick	GA	M87PBC	08/26/88	1.90	11/25/88	3.50	11/25/88	WSU
Brunswick Pulp and Paper	Brunswick	GA	M87PBC1	08/26/88	1.60	11/25/88	2.90	11/25/88	WSU
Champion International	Courtland	AL	M40PAC	06/24/88	3.50	11/18/88	7.60	11/18/88	WSU
Champion International	Quinnesec	MI	Q7P	12/15/87	7.70	03/09/88	50.00	03/09/88	CAL
Champion International	Quinnesec	MI	Q9P	12/15/87	7.80	03/09/88	45.00	03/09/88	CAL
Champion International	Cantonment	FL	CPH300	01/15/88	0.70	09/30/88	4.10	09/30/88	WSU
Champion International	Cantonment	FL	CPH300	01/15/88	1.00	03/21/88	0.70	03/21/88	CAL
Champion International	Canton	NC	M47B100-500	04/21/88	6.00	07/01/88	9.90	07/01/88	WSU
Champion International	Canton	NC	M47D100-500	04/21/88	5.80	07/01/88	10.00	07/01/88	WSU

A-2. TCDD/TCDF CONCENTRATION DATA (CONTINUED)

MATRIX=PULP (ppt)
HARDWOOD

Company	City	State	Sample ID	Sample Date	TCDD	TCDD Date	TCDF	TCDF Date	Lab
Chesapeake Corp.	West Point	VA	M74PC90	12/04/88	8.30	02/17/89	14.00	02/17/89	CAL
Pentair, Inc.	Park Falls	WI	M25PC	07/04/88	0.50	11/25/88	0.90	11/25/88	WSU
Federal Paper Board Co.	Augusta	GA	M83PAC	06/10/88	2.40	11/11/88	7.90	11/11/88	WSU
Federal Paper Board Co.	Augusta	GA	M83PBC	06/10/88	4.90	12/16/88	15.00	12/16/88	WSU
Federal Paper Board Co.	Riegelwood	NC	M16PDC	12/13/88	3.20	01/17/89	1.30	01/17/89	WSU
Federal Paper Board Co.	Riegelwood	NC	M16PDC	12/13/88	3.30	01/17/89	1.50	01/17/89	WSU
Finch, Pruyn & Co., Inc.	Glens Falls	NY	M41PC	01/13/89	0.30	02/24/89	0.30	02/24/89	WSU
Georgia-Pacific Corp.	Crossett	AR	M68PAC	09/02/88	6.00	11/25/88	59.00	11/25/88	WSU
Georgia-Pacific Corp.	Palatka	FL	M24PAC	07/05/88	0.50	11/18/88	0.90	11/18/88	WSU
Georgia-Pacific Corp.	Woodland	ME	M17PC	07/22/88	0.40	12/23/88	0.90	12/23/88	WSU
Georgia-Pacific Corp.	Zachary	LA	M1PAC	07/21/88	16.00	11/25/88	539.00	11/25/88	WSU
Georgia-Pacific Corp.	Zachary	LA	M1PBC	07/21/88	5.20	11/25/88	78.00	11/25/88	WSU
P.H. Glatfelter Co.	Spring Grove	PA	M64PC60	10/28/88	0.40	01/12/89	2.20	01/12/89	CAL
Proctor & Gamble Co.	Mehoopany	PA	M42PC	07/06/88	2.00	12/09/88	1.10	12/09/88	WSU
Scott Paper Co.	Mobile	AL	M26PC190	01/13/89	0.60	04/19/89	0.80	04/19/89	CAL
Scott Paper Co.	Hinckley	ME	M61PCA	06/28/88	1.90	11/18/88	10.00	11/18/88	WSU
Scott Paper Co.	Muskegon	MI	M92PC	06/13/88	0.30	11/11/88	1.00	11/11/88	WSU
Scott Paper Co.	Muskegon	MI	M92PC	06/13/88	0.40	11/11/88	1.40	11/11/88	WSU
Scott Paper Co.	Westbrook	ME	M30PAC	06/30/88	4.20	11/18/88	16.00	11/18/88	WSU
Simpson Paper Co.	Pasadena	TX	M2PBC	10/08/88	4.50	12/23/88	11.00	12/23/88	WSU
Stone Container Corp.	Panama City	FL	M102PC	07/19/88	0.10	12/09/88	6.60	12/09/88	WSU
Temple-Eastex, Inc.	Evadale	TX	M3PBC	07/28/88	3.10	11/25/88	6.30	11/25/88	WSU
Temple-Eastex, Inc.	Evadale	TX	M3PDC	07/28/88	4.10	01/17/89	13.00	01/17/89	WSU
Union Camp Corp.	Eastover	SC	M93PBC	07/22/88	0.40	12/23/88	1.30	12/23/88	WSU
Union Camp Corp.	Franklin	VA	UCH600	05/08/88	1.10	11/03/88	2.10	11/03/88	CAL
Union Camp Corp.	Franklin	VA	UC0400	05/08/88	3.20	01/03/89	3.60	01/03/89	CAL
Westvaco Corp.	Covington	VA	M28PBC	07/19/88	6.20	12/02/88	49.00	12/02/88	WSU
Westvaco Corp.	Covington	VA	M28PCC	07/19/88	5.90	01/17/89	19.00	01/17/89	WSU
Westvaco Corp.	Wickliffe	KY	M78PBC	07/23/88	2.10	12/09/88	25.00	12/09/88	WSU
Weyerhauser Co.	Longview	WA	M45PBC	08/02/88	7.70	12/02/88	20.00	12/02/88	WSU
Weyerhauser Co.	Rothchild	WI	M29PC	08/12/88	15.00	12/09/88	26.00	12/09/88	WSU

SOFTWOOD

Company	City	State	Sample ID	Sample Date	TCDD	TCDD Date	TCDF	TCDF Date	Lab
Gaylord Container Corp.	Antioch	CA	M106PAC	10/15/88	32.00	12/23/88	969.00	12/23/88	WSU
Alaska Pulp Co.	Sitka	AK	M5PC	08/27/88	0.70	12/16/88	1.40	12/16/88	WSU
Kimberly-Clark Corp.	Coosa Pines	AL	M36PBC	08/26/88	4.10	12/02/88	7.30	12/02/88	WSU
Kimberly-Clark Corp.	Coosa Pines	AL	M36PCC	08/26/88	11.00	12/02/88	38.00	12/02/88	WSU
Kimberly-Clark Corp.	Coosa Pines	AL	M36PDC	08/26/88	2.60	12/02/88	3.30	12/02/88	WSU
Gilman Paper Co.	St. Marys	GA	M55PBC	09/02/88	3.70	12/09/88	12.00	12/09/88	WSU
Hammermill Paper Co.	Selma	AL	M88PBC	06/26/88	4.70	12/16/88	22.00	12/16/88	WSU
International Paper Co.	Bastrop	LA	M85PBC	06/20/88	6.30	12/16/88	42.00	12/16/88	WSU
International Paper Co.	Georgetown	SC	M70PAC	07/16/88	9.20	11/04/88	38.00	11/04/88	WSU
International Paper Co.	Georgetown	SC	M70PAC1	07/16/88	10.00	11/04/88	41.00	11/04/88	WSU
International Paper Co.	Georgetown	SC	M70PCC	07/16/88	17.00	12/16/88	55.00	12/16/88	WSU
International Paper Co.	Georgetown	SC	M70PCC1	07/16/88	16.00	12/16/88	52.00	12/16/88	WSU
International Paper Co.	Jay	ME	RG1-86366	01/15/87	26.00	.	140.00	.	WSU
International Paper Co.	Mobile	AL	M71PAC	10/24/88	21.00	12/30/88	106.00	12/30/88	WSU
J ational Paper Co.	Moss Point	MS	M34PAC	06/07/88	7.30	11/11/88	36.00	11/11/88	WSU

A-2. TCDD/TCDF CONCENTRATION DATA (CONTINUED)

MATRIX=PULP (ppt)
SOFTWOOD

Company	City	State	Sample ID	Sample Date	TCDD	TCDD Date	TCDF	TCDF Date	Lab
International Paper Co.	Pine Bluff	AR	M51PBC	06/17/88	5.00	12/02/88	57.00	12/02/88	WSU
International Paper Co.	Texarkana	TX	M99PBC	08/06/88	12.00	12/23/88	81.00	12/23/88	WSU
International Paper Co.	Ticonderoga	NY	M9PBC	06/24/88	31.00	11/04/88	185.00	11/04/88	WSU
ITT-Rayonier, Inc.	Hoquiam	WA	M33PC	07/09/88	0.60	12/09/88	3.80	12/09/88	WSU
ITT-Rayonier, Inc.	Jesup	GA	TTP5	07/24/88	0.60	11/03/88	0.80	11/03/88	CAL
ITT-Rayonier, Inc.	Port Angeles	WA	M12PAC	07/27/88	0.60	12/16/88	2.10	12/16/88	WSU
James River Corp.	Berlin	NH	M89PAC	08/19/88	32.00	11/04/88	1110.00	11/04/88	WSU
James River Corp.	Camas	WA	M32PAC	.	0.20	11/04/88	0.60	11/04/88	WSU
James River Corp.	Camas	WA	M32PCC	.	12.00	11/04/88	152.00	11/04/88	WSU
James River Corp.	Clatskanie	OR	86374612	.	10.20	04/21/87	54.30	04/21/87	WSU
James River Corp.	Clatskanie	OR	86374612	.	11.00	08/19/87	64.40	08/19/87	WSU
James River Corp.	Clatskanie	OR	86374661	.	12.60	04/21/87	63.90	04/21/87	WSU
James River Corp.	St. Francesville	LA	M52PAC	.	6.40	11/04/88	19.00	11/04/88	WSU
James River Corp.	Butler	AL	M96PBC	06/16/88	1.20	11/04/88	1.40	11/04/88	WSU
Leaf River Forest Products	New Augusta	MS	M35DPC60	02/27/88	14.00	02/17/89	23.00	02/17/89	CAL
Leaf River Forest Products	New Augusta	MS	M35SPC60	02/27/88	15.00	02/17/89	35.00	02/17/89	CAL
Longview Fibre Co.	Longview	WA	M53PBC	06/29/88	4.70	12/02/88	18.00	12/02/88	WSU
Longview Fibre Co.	Longview	WA	M53PAC	06/29/88	4.80	12/02/88	.	12/02/88	WSU
Longview Fibre Co.	Longview	WA	M53PAC	06/29/88	4.40	06/19/89	28.00	06/19/89	CAL
Longview Fibre Co.	Longview	WA	M53PAC D	06/29/88	4.70	06/19/89	26.00	06/19/89	CAL
Ketchikan Pulp & Paper Co.	Ketchikan	AK	M31PC	08/15/88	0.30	12/09/88	0.30	12/09/88	WSU
Louisiana Pacific Corp.	Samoa	CA	M7PC70	11/20/88	9.10	01/12/89	59.00	01/12/89	CAL
Mead Corporation	Escanaba	MI	MP15	12/15/87	25.00	03/09/88	116.00	03/09/88	CAL
Nekoosa Papers, Inc.	Ashdown	AR	M20PBC	10/08/88	5.50	12/23/88	12.00	12/23/88	WSU
Pope & Talbot, Inc.	Halsey	OR	M19PC	06/27/88	10.00	11/04/88	41.00	11/04/88	WSU
Potlatch Corp.	Cloquet	MN	M38PC70	09/24/88	2.40	01/12/89	7.90	01/12/89	CAL
Potlatch Corp.	Lewiston	ID	M56PC	07/26/88	25.00	12/02/88	153.00	12/02/88	WSU
Potlatch Corp.	Lewiston	ID	M56PC1	07/26/88	27.00	12/02/88	147.00	12/02/88	WSU
Potlatch Corp.	McGhee	AR	M18PAC	07/15/88	21.00	12/02/88	59.00	12/02/88	WSU
Alabama River Pulp	Claiborne	AL	M21PBC	06/07/88	43.00	11/11/88	120.00	11/11/88	WSU
Boise Cascade Corp.	Deridder	LA	M58PC	06/10/88	5.30	11/11/88	8.70	11/11/88	WSU
Boise Cascade Corp.	St. Helens	OR	M76PC70	02/24/89	6.50	04/19/89	18.00	04/19/89	CAL
Boise Cascade Corp.	St. Helens	OR	M76PC60	06/27/88	4.20	04/19/89	12.00	04/19/89	CAL
Boise Cascade Corp.	St. Helens	OR	M76PC600	02/24/89	4.40	04/19/89	11.00	04/19/89	CAL
Boise Cascade Corp.	Rumford	ME	M82PAC	06/02/88	116.00	11/11/88	800.00	11/11/88	WSU
Boise Cascade Corp.	Wallula	WA	M66PAC	07/15/88	56.00	11/04/88	1380.00	11/04/88	WSU
Boise Cascade Corp.	International Falls	MN	DE020902	.	15.20	03/19/87	.	.	WSU
Boise Cascade Corp.	International Falls	MN	DE020902	.	16.30	04/21/87	333.00	04/21/87	WSU
Bowater Corp.	Catawba	SC	M23PC	06/17/88	2.10	11/18/88	3.30	11/18/88	WSU
Bowater Corp.	Calhoun	TN	M75PC	06/24/88	7.70	11/11/88	53.00	11/11/88	WSU
Brunswick Pulp and Paper	Brunswick	GA	M87PCC	08/26/88	3.60	11/25/88	4.30	11/25/88	WSU
Brunswick Pulp and Paper	Brunswick	GA	M87PDC	08/26/88	8.30	11/25/88	12.00	11/25/88	WSU
Brunswick Pulp and Paper	Brunswick	GA	M87PAC	08/26/88	6.30	11/25/88	8.00	11/25/88	WSU
Brunswick Pulp and Paper	Brunswick	GA	M87PAC1	08/26/88	6.10	11/25/88	9.40	11/25/88	WSU
Buckeye Cellulose	Perry	FL	M91PC80	.	0.50	11/03/88	0.70	11/03/88	CAL
Buckeye Cellulose	Perry	FL	M91PC90	.	0.80	11/03/88	2.50	11/03/88	CAL
Buckeye Cellulose	Oglethorpe	GA	M22PC40	07/23/88	0.50	11/03/88	0.90	11/03/88	CAL
Champion International	Lufkin	TX	DF24410	12/03/86	1.00	.	1.20	.	WSU
Champion International	Lufkin	TX	DF024411	.	3.89	04/21/87	7.68	04/21/87	WSU
Champion International	Lufkin	TX	DF024411	.	3.99	08/19/87	7.90	08/19/87	WSU
Champion International	Courtland	AL	M40PBC	06/24/88	23.00	11/18/88	102.00	11/18/88	WSU
Champion International	Cantonment	FL	CPS300	01/15/88	2.00	09/30/88	2.20	09/30/88	WSU
Champion International	Cantonment	FL	CPS300	01/15/88	2.00	03/21/88	0.90	03/21/88	CAL

A-2. TCDD/TCDF CONCENTRATION DATA (CONTINUED)

MATRIX=PULP (ppt)
SOFTWOOD

Company	City	State	Sample ID	Sample Date	TCDD	TCDD Date	TCDF	TCDF Date	Lab
Champion International	Cantonment	FL	CPS302	01/15/88	4.90	03/21/88	1.10	03/21/88	CAL
Champion International	Houston	TX	M15PC	10/07/88	4.90	12/23/88	6.80	12/23/88	WSU
Champion International	Canton	NC	M47A100-500	04/21/88	17.00	07/01/88	27.00	07/01/88	WSU
Champion International	Canton	NC	M47C100-500	04/21/88	6.50	07/01/88	11.00	07/01/88	WSU
Champion International	Canton	NC	M47C100-500Q	04/21/88	4.60	10/06/88	5.50	10/06/88	WSU
Federal Paper Board Co.	Augusta	GA	M83PCC	06/10/88	7.90	12/16/88	19.00	12/16/88	WSU
Federal Paper Board Co.	Riegelwood	NC	M16PAC	12/13/88	4.00	01/17/89	3.20	01/17/89	WSU
Federal Paper Board Co.	Riegelwood	NC	M16PBC	12/13/88	4.30	01/17/89	4.70	01/17/89	WSU
Georgia-Pacific Corp.	Bellingham	WA	M60PC	07/22/88	2.60	12/09/88	449.00	12/09/88	WSU
Georgia-Pacific Corp.	Bellingham	WA	M60PC1	07/22/88	3.50	06/19/89	409.00	06/19/89	CAL
Georgia-Pacific Corp.	Crosset	AR	M68PBC	09/02/88	7.70	11/25/88	89.00	11/25/88	WSU
Georgia-Pacific Corp.	Crosset	AR	M68PCC	09/02/88	19.00	11/25/88	308.00	11/25/88	WSU
Georgia-Pacific Corp.	Palatka	FL	M24PBC	07/05/88	0.50	11/18/88	2.40	11/18/88	WSU
Georgia-Pacific Corp.	Zachery	LA	M1PCC	07/21/88	27.00	11/25/88	632.00	11/25/88	WSU
P.H. Glatfelter Co.	Spring Grove	PA	M64PC50	10/28/88	3.90	01/12/89	13.00	01/12/89	CAL
P.H. Glatfelter Co.	Spring Grove	PA	M64PC50D	10/28/88	6.50	01/12/89	18.00	01/12/89	CAL
Scott Paper Co.	Everett	WA	M80PAC	07/17/88	0.30	12/30/88	0.10	12/30/88	WSU
Scott Paper Co.	Mobile	AL	M26PC150	10/24/88	2.20	06/19/89	4.30	06/19/89	CAL
Scott Paper Co.	Mobile	AL	M26PC180	01/13/89	1.70	04/19/89	2.20	04/19/89	CAL
Scott Paper Co.	Hinckley	ME	M61PCB	06/28/88	8.50	11/18/88	37.00	11/18/88	WSU
Scott Paper Co.	Hinckley	ME	M61PCB1	06/28/88	7.90	11/18/88	35.00	11/18/88	WSU
Scott Paper Co.	Westbrook	ME	M30PBC	06/30/88	8.10	11/18/88	30.00	11/18/88	WSU
Simpson Paper Co.	Anderson	CA	M98PC	06/24/88	49.00	11/11/88	2620.00	11/11/88	WSU
Simpson Paper Co.	Fairhaven	CA	M43PC60	08/06/88	20.00	11/03/88	106.00	11/03/88	CAL
Simpson Paper Co.	Pasadena	TX	M2PAC	10/08/88	14.00	12/23/88	48.00	12/23/88	WSU
Simpson Paper Co.	Pasadena	TX	M2PAC1	10/08/88	18.00	12/23/88	66.00	12/23/88	WSU
Simpson Paper Co.	Tacoma	WA	M81PC	10/29/88	12.00	12/30/88	38.00	12/30/88	WSU
St. Joe Paper Co.	Port St. Joe	FL	M94PC	08/02/88	2.20	12/23/88	5.70	12/23/88	WSU
Stone Container Corp.	Missoula	MT	M27PC	07/12/88	4.10	11/18/88	13.00	11/18/88	WSU
Stone Container Corp.	Snowflake	AZ	M100PC	07/17/88	0.70	12/23/88	1.30	12/23/88	WSU
Temple-Eastex, Inc.	Evadale	TX	M3PAC	07/28/88	1.90	11/25/88	9.60	11/25/88	WSU
Temple-Eastex, Inc.	Evadale	TX	M3PCC	07/28/88	7.80	11/25/88	22.00	11/25/88	WSU
Union Camp Corp.	Eastover	SC	M93PAC	07/22/88	2.40	12/23/88	5.60	12/23/88	WSU
Union Camp Corp.	Franklin	VA	UCA100	05/08/88	3.80	11/03/88	4.20	11/03/88	CAL
Union Camp Corp.	Franklin	VA	UCS600	05/08/88	5.20	11/03/88	5.70	11/03/88	CAL
Union Camp Corp.	Franklin	VA	UCS6000	05/08/88	5.40	11/03/88	6.90	11/03/88	CAL
Westvaco Corp.	Covington	VA	M28PAC	07/19/88	13.00	12/02/88	105.00	12/02/88	WSU
Westvaco Corp.	Luke	MD	M62PC	06/28/88	29.00	11/18/88	157.00	11/18/88	WSU
Westvaco Corp.	Wickliffe	KY	M78PAC	07/23/88	12.00	12/09/88	55.00	12/09/88	WSU
Westvaco Corp.	Wickliffe	KY	M78PACD	07/23/88	11.00	12/09/88	54.00	12/09/88	WSU
Weyerhauser Co.	Cosmopolis	WA	M4PAC	08/06/88	1.00	12/09/88	6.30	12/09/88	WSU
Weyerhauser Co.	Cosmopolis	WA	M4PAC1	08/06/88	.	12/09/88	6.40	12/09/88	WSU
Weyerhauser Co.	Everett	WA	M79PAC	07/24/88	3.40	12/16/88	16.00	12/16/88	WSU
Weyerhauser Co.	Longview	WA	M45PAC	08/02/88	1.70	12/02/88	2.80	12/02/88	WSU
Weyerhauser Co.	Longview	WA	M45PAC1	08/02/88	1.60	12/02/88	2.80	12/02/88	WSU
Weyerhauser Co.	New Bern	NC	M6PAC	08/13/88	7.50	11/18/88	45.00	11/18/88	WSU
Weyerhauser Co.	Plymouth	NC	M86PC80	02/13/89	14.00	04/19/89	222.00	04/19/89	CAL

A-2. TCDD/TCDF CONCENTRATION DATA (CONTINUED)

MATRIX=SLUDGE (ppt)

Company	City	State	Sample ID	Sample Date	TCDD	TCDD Date	TCDF	TCDF Date	Lab
Gaylord Container Corp.	Antioch	CA	M106SC	10/15/88	101.00	01/03/89	1570.00	01/03/89	CAL
Alaska Pulp Co.	Sitka	AK	M5SC-1	08/27/88	4.70	06/29/89	42.00	06/29/89	CAL
Lincoln Pulp and Paper	Lincoln	ME	M11SC	11/19/88	48.00	01/26/89	223.00	01/26/89	CAL
Wausau Paper Mills Co.	Brokaw	WI	M54SC	07/22/88	3.20	12/22/88	68.00	12/22/88	CAL
Wausau Paper Mills Co.	Brokaw	WI	M54SC	07/22/88	4.10	06/29/89	56.00	06/29/89	CAL
Gulf States Paper Corp.	Demopolis	AL	M101SC	06/14/88	51.00	12/06/88	.	12/06/88	CAL
Gulf States Paper Corp.	Demopolis	AL	M101SC	06/14/88	37.00	10/06/89	107.00	10/06/89	CAL
Hammermill Paper Co.	Erie	PA	M103SC	06/19/88	1.40	12/22/88	3.00	12/22/88	CAL
Hammermill Paper Co.	Erie	PA	M103SC	06/19/88	0.90	03/01/89	3.10	03/01/89	CAL
International Paper Co.	Bastrop	LA	M85SC	06/20/88	140.00	01/03/89	677.00	01/03/89	CAL
International Paper Co.	Georgetown	SC	M70SC	07/16/88	62.00	12/06/88	161.00	12/06/88	CAL
International Paper Co.	Jay	ME	RG1-86397	01/15/87	500.00	.	2100.00	.	WSU
International Paper Co.	Jay	ME	RG186387	.	193.00	04/21/87	879.00	04/21/87	WSU
International Paper Co.	Jay	ME	RG186387	.	168.00	08/19/87	670.00	08/19/87	WSU
International Paper Co.	Jay	ME	RG186387A	.	191.00	08/26/87	762.00	08/26/87	WSU
International Paper Co.	Jay	ME	RG186387B	.	161.00	08/26/87	713.00	08/26/87	WSU
International Paper Co.	Mobile	AL	M71SC	10/24/88	108.00	01/26/89	617.00	01/26/89	CAL
International Paper Co.	Moss Point	MS	M34SC	06/07/88	161.00	12/06/88	1020.00	12/06/88	CAL
International Paper Co.	Natchez	MS	M97SC	08/12/88	14.00	11/03/88	78.00	11/03/88	CAL
International Paper Co.	Pine Bluff	AR	M51SC	06/17/88	185.00	12/06/88	2940.00	12/06/88	CAL
International Paper Co.	Texarkana	TX	M99SC	08/06/88	71.00	01/03/89	1000.00	01/03/89	CAL
International Paper Co.	Texarkana	TX	M99SC	08/06/88	86.00	06/19/89	387.00	06/19/89	CAL
International Paper Co.	Texarkana	TX	M99SC1	08/06/88	.	01/03/89	600.00	01/03/89	CAL
International Paper Co.	Ticonderoga	NY	M9SAC	06/24/88	59.00	12/06/88	267.00	12/06/88	CAL
International Paper Co.	Ticonderoga	NY	M9SBC	06/24/88	306.00	12/06/88	2470.00	12/06/88	CAL
ITT-Rayonier, Inc.	Fernandina Beach	FL	M90SC	07/06/88	4.70	06/29/89	32.00	06/29/89	CAL
ITT-Rayonier, Inc.	Hoquiam	WA	M33SC	07/09/88	4.80	06/29/89	25.00	06/29/89	CAL
ITT-Rayonier, Inc.	Jesup	GA	M84SC	07/24/88	3.00	02/17/89	2.40	02/17/89	CAL
ITT-Rayonier, Inc.	Port Angeles	WA	M12SAC	07/27/88	47.00	06/29/89	65.00	06/29/89	CAL
James River Corp.	Berlin	NH	M89SC	08/19/88	104.00	12/19/88	2930.00	12/19/88	CAL
James River Corp.	Berlin	NH	M89SC	08/19/88	98.00	06/19/89	2170.00	06/19/89	CAL
James River Corp.	Camas	WA	M32SC	.	12.00	12/06/88	105.00	12/06/88	CAL
James River Corp.	Clatskanie	OR	86374641	09/10/86	19.00	.	100.00	.	WSU
James River Corp.	Clatskanie	OR	86374642	09/10/86	89.00	.	810.00	.	WSU
James River Corp.	Green Bay	WI	M72SBC	.	35.00	12/22/88	250.00	12/22/88	CAL
James River Corp.	Old Town	ME	M8SAC	.	12.00	12/06/88	34.00	12/06/88	CAL
James River Corp.	St. Francesville	LA	M52SAC	.	96.00	12/06/88	243.00	12/06/88	CAL
Leaf River Forest Products	New Augusta	MS	M35SSC10	02/27/88	681.00	02/17/89	.	02/17/89	CAL
Longview Fibre Co.	Longview	WA	M53SC	06/29/88	69.00	12/22/88	437.00	12/22/88	CAL
Ketchikan Pulp & Paper Co.	Ketchikan	AK	M31SC	08/15/88	3.50	06/29/89	.	06/29/89	CAL
Ketchikan Pulp & Paper Co.	Ketchikan	AK	M31SC	08/15/88	0.40	.	2.00	.	CAL
Mead Corporation	Chillicothe	OH	DE026011	.	3.37	04/21/87	42.60	04/21/87	WSU
Mead Corporation	Chillicothe	OH	DE026011	.	3.27	08/19/87	34.50	08/19/87	WSU
Mead Corporation	Escanaba	MI	MS15	12/15/87	125.00	09/30/88	574.00	09/30/88	WSU
Mead Corporation	Kingsport	TN	M73SC	06/06/88	3.00	01/26/89	25.00	01/26/89	CAL
Nekoosa Papers, Inc.	Nekoosa & Port Edwards	WI	M77SC	06/17/88	109.00	12/22/88	1300.00	12/22/88	CAL
Nekoosa Papers, Inc.	Ashdown	AR	M20SC	10/08/88	13.00	01/26/89	30.00	01/26/89	CAL
Pope & Talbot, Inc.	Halsey	OR	M19SC	06/27/88	31.00	12/06/88	106.00	12/06/88	CAL
Potlatch Corp.	Cloquet	MN	M38SCO	09/24/88	·5.00	01/26/89	25.00	01/26/89	CAL
Potlatch Corp.	Lewiston	ID	M56SC	07/26/88	78.00	01/26/89	639.00	01/26/89	CAL
Potlatch Corp.	McGhee	AR	M18SC	07/15/88	91.00	12/19/88	433.00	12/19/88	CAL
Alabama River Pulp	Claiborne	AL	M21SC	06/07/88	81.00	12/06/88	373.00	12/06/88	CAL
Alabama River Pulp	Claiborne	AL	M21SC1	06/07/88	73.00	12/06/88	393.00	12/06/88	CAL
Alabama River Pulp	Claiborne	AL	M21SC2	06/07/88	68.00	01/26/89	342.00	01/26/89	CAL

A-2. TCDD/TCDF CONCENTRATION DATA (CONTINUED)

MATRIX=SLUDGE (ppt)

Company	City	State	Sample ID	Sample Date	TCDD	TCDD Date	TCDF	TCDF Date	Lab
Appleton Papers, Inc.	Roaring Springs	PA	M13SC0	06/26/88	5.00	11/03/88	113.00	11/03/88	CAL
Boise Cascade Corp.	Jackson	AL	M65SC	06/17/88	18.00	12/22/88	147.00	12/22/88	CAL
Boise Cascade Corp.	Jackson	AL	M65SC1	06/17/88	18.00	12/22/88	169.00	12/22/88	CAL
Boise Cascade Corp.	St. Helens	OR	M76SCO	02/24/89	4.20	04/19/89	25.00	04/19/89	CAL
Boise Cascade Corp.	Rumford	ME	M82SC	06/02/88	105.00	12/06/88	674.00	12/06/88	CAL
Boise Cascade Corp.	Wallula	WA	M66SC	07/15/88	70.00	12/22/88	1490.00	12/22/88	CAL
Boise Cascade Corp.	International Falls	MN	DE020720	06/25/86	24.00	.	380.00	.	WSU
Boise Cascade Corp.	International Falls	MN	DE020820	06/25/86	710.00	.	10900.00	.	WSU
Boise Cascade Corp.	International Falls	MN	DE020920	.	37.40	03/19/87	624.00	03/19/87	WSU
Boise Cascade Corp.	International Falls	MN	DE020920	.	35.80	04/21/87	732.00	04/21/87	WSU
Brunswick Pulp and Paper	Brunswick	GA	M87SC	08/26/88	33.00	01/03/89	62.00	01/03/89	CAL
Buckeye Cellulose	Perry	FL	M91SCO	.	12.00	11/03/88	40.00	11/03/88	CAL
Buckeye Cellulose	Oglethorpe	GA	M22SC10	07/23/88	2.60	11/03/88	6.10	11/03/88	CAL
Buckeye Cellulose	Oglethorpe	GA	M22SC10	07/23/88	2.60	11/03/88	3.00	01/31/89	CAL
Champion International	Lufkin	TX	DF024514	12/03/86	17.00	.	32.00	.	WSU
Champion International	Lufkin	TX	DF024519	12/03/86	36.00	.	78.00	.	WSU
Champion International	Lufkin	TX	DF024513	.	17.60	03/19/87	33.70	03/19/87	WSU
Champion International	Lufkin	TX	DF024606	.	19.20	04/21/87	35.70	04/21/87	WSU
Champion International	Lufkin	TX	DF024606	.	17.40	08/19/87	31.90	08/19/87	WSU
Champion International	Courtland	AL	M40SC	06/24/88	215.00	12/22/88	923.00	12/22/88	CAL
Champion International	Quinnesec	MI	Q11S	12/15/87	95.00	09/30/88	735.00	09/30/88	WSU
Champion International	Cantonment	FL	CP1	01/15/88	14.00	11/03/88	21.00	11/03/88	CAL
Champion International	Houston	TX	M15SC	10/07/88	106.00	01/03/89	144.00	01/03/89	CAL
Champion International	Canton	NC	M47J100-500	04/21/88	175.00	07/01/88	.	07/01/88	WSU
Champion International	Canton	NC	M47J100-500Q	04/21/88	172.00	10/06/88	260.00	10/06/88	WSU
Chesapeake Corp.	West Point	VA	M74SC150	12/04/88	14.00	02/17/89	47.00	02/17/89	CAL
Container Corp. of America	Brewton	AL	M67SC	07/01/88	16.00	12/22/88	34.00	12/22/88	CAL
Pentair, Inc.	Park Falls	WI	M25SC	07/04/88	9.40	12/19/88	90.00	12/19/88	CAL
Pentair, Inc.	Park Falls	WI	M25SC	07/05/88	11.00	06/29/89	73.00	06/29/89	CAL
Federal Paper Board Co.	Riegelwood	NC	M16SC	12/13/88	3.80	04/19/89	5.20	04/19/89	CAL
Federal Paper Board Co.	Riegelwood	NC	M16SCO	12/13/88	2.90	04/19/89	3.30	04/19/89	CAL
Finch, Pruyn & Co., Inc.	Glens Falls	NY	M41SC	01/13/89	3.70	06/29/89	.	06/29/89	CAL
Finch, Pruyn & Co., Inc.	Glens Falls	NY	M41SC	01/13/89	1.20	.	7.40	.	CAL
Georgia-Pacific Corp.	Bellingham	WA	M60SC1	07/22/88	19.00	06/29/89	584.00	06/29/89	CAL
Georgia-Pacific Corp.	Crosset	AR	M68SBC	09/02/88	168.00	12/22/88	168.00	12/22/88	CAL
Georgia-Pacific Corp.	Woodland	ME	M17SC	07/22/88	1.90	12/19/88	7.30	12/19/88	CAL
Georgia-Pacific Corp.	Zachary	LA	M1SC	07/21/88	17.00	12/19/88	421.00	12/19/88	CAL
P.H. Glatfelter Co.	Spring Grove	PA	M64SC00	10/28/88	93.00	06/19/89	238.00	06/19/89	CAL
Proctor & Gamble Co.	Mehoopany	PA	M42SBC	07/06/88	2.30	06/29/89	.	06/29/89	CAL
Proctor & Gamble Co.	Mehoopany	PA	M42SBC	07/06/88	0.30	.	0.70	.	CAL
Scott Paper Co.	Everett	WA	M80SC	07/17/88	14.00	08/02/89	72.00	08/02/89	CAL
Scott Paper Co.	Mobile	AL	M26SC220	01/13/89	9.50	04/19/89	18.00	04/19/89	CAL
Scott Paper Co.	Hinckley	ME	M61SCB	06/28/88	6.90	12/06/88	29.00	12/06/88	CAL
Scott Paper Co.	Hinckley	ME	M61SCC1	06/28/88	67.00	12/06/88	330.00	12/06/88	CAL
Scott Paper Co.	Hinckley	ME	M61SCA	06/28/88	33.00	12/06/88	106.00	12/06/88	CAL
Scott Paper Co.	Hinckley	ME	M61SCA1	06/28/88	39.00	12/06/88	149.00	12/06/88	CAL
Scott Paper Co.	Westbrook	ME	M30SC	06/30/88	13.00	12/19/88	55.00	12/19/88	CAL
Simpson Paper Co.	Anderson	CA	M98SC	06/24/88	278.00	01/03/89	6740.00	01/03/89	CAL
Simpson Paper Co.	Tacoma	WA	M81DSCO	08/01/89	30.00	.	176.00	.	CAL
Simpson Paper Co.	Tacoma	WA	M81SC	10/29/88	.	01/03/89	87.00	01/03/89	CAL
Simpson Paper Co.	Tacoma	WA	M81SC	10/29/88	39.00	06/19/89	101.00	06/19/89	CAL
Simpson Paper Co.	Tacoma	WA	M81SC D	10/29/88	29.00	06/19/89	106.00	06/19/89	CAL
Stone Container Corp.	Panama City	FL	M102SC	07/19/88	3.60	12/22/88	16.00	12/22/88	CAL

A-2. TCDD/TCDF CONCENTRATION DATA (CONTINUED)

MATRIX-SLUDGE (ppt)

Company	City	State	Sample ID	Sample Date	TCDD	TCDD Date	TCDF	TCDF Date	Lab
Temple-Eastex, Inc.	Evadale	TX	M3S3	07/28/88	16.00	12/06/88	49.00	12/06/88	CAL
Union Camp Corp.	Eastover	SC	M93SC	07/22/88	6.90	01/03/89	13.00	01/03/89	CAL
Union Camp Corp.	Franklin	VA	UCF10	05/08/88	3.60	11/03/88	6.00	11/03/88	CAL
Westvaco Corp.	Covington	VA	M28SC	07/19/88	119.00	12/19/88	799.00	12/19/88	CAL
Westvaco Corp.	Luke	MD	M62SC	06/28/88	80.00	12/22/88	471.00	12/22/88	CAL
Westvaco Corp.	Wickliffe	KY	M78SC	07/23/88	9.40	12/22/88	46.00	12/22/88	CAL
Weyerhauser Co.	Cosmopolis	WA	M4SC1	08/06/88	12.00	06/29/89	61.00	06/29/89	CAL
Weyerhauser Co.	Longview	WA	M45SC-L	08/02/88	25.00	12/22/88	80.00	12/22/88	CAL
Weyerhauser Co.	Longview	WA	M45SC1-L	08/02/88	.	12/22/88	84.00	12/22/88	CAL
Weyerhauser Co.	Longview	WA	M45SC1-L	08/02/88	35.00	03/01/89	89.00	03/01/89	CAL
Weyerhauser Co.	New Bern	NC	M6SC	08/13/88	373.00	12/19/88	1920.00	12/19/88	CAL
Weyerhauser Co.	New Bern	NC	M6SC1	08/13/88	213.00	12/19/88	1600.00	12/19/88	CAL
Weyerhauser Co.	Plymouth	NC	M86SCO	02/13/89	1390.00	04/19/89	17100.00	04/19/89	CAL
Weyerhauser Co.	Rothchild	WI	M29SC	08/12/88	58.00	12/19/88	150.00	12/19/88	CAL

MATRIX-SLURRY (ppq)

Company	City	State	Sample ID	Sample Date	TCDD	TCDD Date	TCDF	TCDF Date	Lab
Wilamette Industries	Hawesville	KY	M63SAC	10/28/88	83.00	01/26/89	380.00	01/26/89	CAL
Wilamette Industries	Hawesville	KY	M63SBC	10/28/88	52.00	01/26/89	210.00	01/26/89	CAL
Badger Paper Mills, Inc.	Peshtigo	WI	M46SC	07/22/88	36.00	12/06/88	1800.00	12/06/88	CAL
Kimberly-Clark Corp.	Coosa Pines	AL	M36SC	08/26/88	3800.00	12/06/88	9200.00	12/06/88	CAL
Gilman Paper Co.	St. Marys	GA	M55SC	09/02/88	220.00	12/06/88	610.00	12/06/88	CAL
Hammermill Paper Co.	Selma	AL	M88SC	06/26/88	680.00	12/06/88	2900.00	12/06/88	CAL
James River Corp.	Butler	AL	M96SC	06/16/88	330.00	12/06/88	1100.00	12/06/88	CAL
Boise Cascade Corp.	Deridder	LA	M58SC	06/10/88	280.00	12/06/88	440.00	12/06/88	CAL
Bowater Corp.	Catawba	SC	M23SC	06/17/88	620.00	12/06/88	880.00	12/06/88	CAL
Bowater Corp.	Calhoun	TN	M75SC	06/24/88	.	12/22/88	17000.00	12/22/88	CAL
Bowater Corp.	Calhoun	TN	M75SC	06/24/88	4500.00	02/14/89	14000.00	02/14/89	CAL
Federal Paper Board Co.	Augusta	GA	M83SC	06/10/88	680.00	01/03/89	1400.00	01/03/89	CAL
Georgia-Pacific Corp.	Crosset	AR	M68SAC1	09/02/88	.	12/22/88	740.00	12/22/88	CAL
Georgia-Pacific Corp.	Crosset	AR	M68SAC1	09/02/88	190.00	02/14/89	710.00	02/14/89	CAL
Georgia-Pacific Corp.	Palatka	FL	M24SC	07/05/88	92.00	12/06/88	410.00	12/06/88	CAL
Proctor & Gamble Co.	Mehoopany	PA	M42SAC	07/06/88	6.00	06/29/89	6.00	06/29/89	CAL
Stone Container Corp.	Missoula	MT	M27SC	07/12/88	55.00	12/06/88	150.00	12/06/88	CAL

A-2. TCDD/TCDF CONCENTRATION DATA (CONTINUED)

MATRIX=EFFLUENT (ppq)

Company	City	State	Sample ID	Sample Date	TCDD	TCDD Date	TCDF	TCDF Date	Lab
Proctor & Gamble Co.	Mehoopany	PA	M42EC	07/06/88	9.70	06/28/89	2.80	06/28/89	CAL
Scott Paper Co.	Everett	WA	M80EAC	07/17/88	7.50	06/28/89	29.00	06/28/89	CAL
Scott Paper Co.	Everett	WA	M80EBC	07/17/88	8.30	06/28/89	2.60	06/28/89	CAL
Scott Paper Co.	Mobile	AL	M26EC210	01/13/89	14.00	02/17/89	19.00	02/17/89	CAL
Scott Paper Co.	Hinckley	ME	M61EC	06/28/88	16.00	12/19/88	63.00	12/19/88	CAL
Scott Paper Co.	Hinckley	ME	M61EC1	06/28/88	19.00	12/19/88	100.00	12/19/88	CAL
Scott Paper Co.	Muskegon	MI	M92EC	06/13/88	8.40	12/06/88	42.00	12/06/88	CAL
Scott Paper Co.	Westbrook	ME	M30EC	06/30/88	6.30	11/22/88	12.00	11/22/88	CAL
Simpson Paper Co.	Anderson	CA	M98EC	06/24/88	250.00	11/22/88	8400.00	11/22/88	CAL
Simpson Paper Co.	Fairhaven	CA	M43ECO	08/06/88	100.00	11/03/88	660.00	11/03/88	CAL
Simpson Paper Co.	Pasadena	TX	M2EC	10/08/88	.	01/03/89	1400.00	01/03/89	CAL
Simpson Paper Co.	Pasadena	TX	XM2EC	08/14/89	250.00	.	730.00	.	CAL
Simpson Paper Co.	Tacoma	WA	M81DECO	08/01/89	17.00	.	100.00	.	CAL
Simpson Paper Co.	Tacoma	WA	M81EC	10/29/88	.	01/03/89	27.00	01/03/89	CAL
Simpson Paper Co.	Tacoma	WA	M81EC	10/29/88	.	05/31/89	26.00	05/31/89	CAL
Simpson Paper Co.	Tacoma	WA	M81EC	10/29/88	.	01/03/89	26.00	01/13/89	CAL
Simpson Paper Co.	Tacoma	WA	M81EC1	10/29/88	.	05/31/89	22.00	05/31/89	CAL
St. Joe Paper Co.	Port St. Joe	FL	M94EC1	08/02/88	21.00	02/16/89	60.00	02/16/89	CAL
Stone Container Corp.	Missoula	MT	M27EC	07/12/88	3.10	11/15/88	7.60	11/15/88	CAL
Stone Container Corp.	Panama City	FL	M102EAC	07/19/88	8.40	11/22/88	7.90	11/22/88	CAL
Stone Container Corp.	Panama City	FL	M102EBC	07/19/88	6.90	11/22/88	18.00	11/22/88	CAL
Stone Container Corp.	Snowflake	AZ	M100EC	07/17/88	5.50	11/22/88	39.00	11/22/88	CAL
Temple-Eastex, Inc.	Evadale	TX	M3EC	07/28/88	88.00	05/31/89	100.00	05/31/89	CAL
Union Camp Corp.	Eastover	SC	M93EC	07/22/88	20.00	11/22/88	53.00	11/22/88	CAL
Union Camp Corp.	Franklin	VA	UCF1000	05/08/88	68.00	11/03/88	71.00	11/03/88	CAL
Westvaco Corp.	Covington	VA	M28EC	07/19/88	180.00	11/22/88	520.00	11/22/88	CAL
Westvaco Corp.	Luke	MD	M62EC	06/28/88	16.00	12/19/88	49.00	12/19/88	CAL
Westvaco Corp.	Wickliffe	KY	M78EC	07/23/88	35.00	12/06/88	150.00	12/06/88	CAL
Weyerhauser Co.	Cosmopolis	WA	M4EC	08/05/88	9.70	06/28/89	400.00	06/28/89	CAL
Weyerhauser Co.	Everett	WA	M79EC	07/24/88	33.00	11/15/88	260.00	11/15/88	CAL
Weyerhauser Co.	Longview	WA	M45EC-L	08/02/88	10.00	11/15/88	37.00	11/15/88	CAL
Weyerhauser Co.	Longview	WA	M45EC1-L	08/02/88	8.50	11/15/88	21.00	11/15/88	CAL
Weyerhauser Co.	New Bern	NC	M6EC	08/13/88	44.00	12/06/88	180.00	12/06/88	CAL
Weyerhauser Co.	Plymouth	NC	M86ECO	02/13/89	320.00	04/19/89	4000.00	04/19/89	CAL
Weyerhauser Co.	Rothchild	WI	M29EC	08/12/88	12.00	12/19/88	24.00	12/19/88	CAL
Weyerhauser Co.	Rothchild	WI	M29EC	08/12/88	12.00	06/28/89	18.00	06/28/89	CAL

A-2. TCDD/TCDF CONCENTRATION DATA (CONTINUED)

MATRIX-EFFLUENT (ppq)

Company	City	State	Sample ID	Sample Date	TCDD	TCDD Date	TCDF	TCDF Date	Lab
Proctor & Gamble Co.	Mehoopany	PA	M42EC	07/06/88	9.70	06/28/89	2.80	06/28/89	CAL
Scott Paper Co.	Everett	WA	M80EAC	07/17/88	7.50	06/28/89	29.00	06/28/89	CAL
Scott Paper Co.	Everett	WA	M80EBC	07/17/88	8.30	06/28/89	2.60	06/28/89	CAL
Scott Paper Co.	Mobile	AL	M26EC210	01/13/89	14.00	02/17/89	19.00	02/17/89	CAL
Scott Paper Co.	Hinckley	ME	M61EC	06/28/88	16.00	12/19/88	63.00	12/19/88	CAL
Scott Paper Co.	Hinckley	ME	M61EC1	06/28/88	19.00	12/19/88	100.00	12/19/88	CAL
Scott Paper Co.	Muskegon	MI	M92EC	06/13/88	8.40	12/06/88	42.00	12/06/88	CAL
Scott Paper Co.	Westbrook	ME	M30EC	06/30/88	6.30	11/22/88	12.00	11/22/88	CAL
Simpson Paper Co.	Anderson	CA	M98EC	06/24/88	250.00	11/22/88	8400.00	11/22/88	CAL
Simpson Paper Co.	Fairhaven	CA	M43ECO	08/06/88	100.00	11/03/88	660.00	11/03/88	CAL
Simpson Paper Co.	Pasadena	TX	M2EC	10/08/88	.	01/03/89	1400.00	01/03/89	CAL
Simpson Paper Co.	Pasadena	TX	XM2EC	08/14/89	250.00	.	730.00	.	CAL
Simpson Paper Co.	Tacoma	WA	M81DECO	08/01/89	17.00	.	100.00	.	CAL
Simpson Paper Co.	Tacoma	WA	M81EC	10/29/88	.	01/03/89	27.00	01/03/89	CAL
Simpson Paper Co.	Tacoma	WA	M81EC	10/29/88	.	05/31/89	26.00	05/31/89	CAL
Simpson Paper Co.	Tacoma	WA	M81EC	10/29/88	.	01/03/89	26.00	01/13/89	CAL
Simpson Paper Co.	Tacoma	WA	M81EC1	10/29/88	.	05/31/89	22.00	05/31/89	CAL
St. Joe Paper Co.	Port St. Joe	FL	M94EC1	08/02/88	21.00	02/16/89	60.00	02/16/89	CAL
Stone Container Corp.	Missoula	MT	M27EC	07/12/88	3.10	11/15/88	7.60	11/15/88	CAL
Stone Container Corp.	Panama City	FL	M102EAC	07/19/88	8.40	11/22/88	7.90	11/22/88	CAL
Stone Container Corp.	Panama City	FL	M102EBC	07/19/88	6.90	11/22/88	18.00	11/22/88	CAL
Stone Container Corp.	Snowflake	AZ	M100EC	07/17/88	5.50	11/22/88	39.00	11/22/88	CAL
Temple-Eastex, Inc.	Evadale	TX	M3EC	07/28/88	88.00	05/31/89	100.00	05/31/89	CAL
Union Camp Corp.	Eastover	SC	M93EC	07/22/88	20.00	11/22/88	53.00	11/22/88	CAL
Union Camp Corp.	Franklin	VA	UCF1000	05/08/88	68.00	11/03/88	71.00	11/03/88	CAL
Westvaco Corp.	Covington	VA	M28EC	07/19/88	180.00	11/22/88	520.00	11/22/88	CAL
Westvaco Corp.	Luke	MD	M62EC	06/28/88	16.00	12/19/88	49.00	12/19/88	CAL
Westvaco Corp.	Wickliffe	KY	M78EC	07/23/88	35.00	12/06/88	150.00	12/06/88	CAL
Weyerhauser Co.	Cosmopolis	WA	M4EC	08/05/88	9.70	06/28/89	400.00	06/28/89	CAL
Weyerhauser Co.	Everett	WA	M79EC	07/24/88	33.00	11/15/88	260.00	11/15/88	CAL
Weyerhauser Co.	Longview	WA	M45EC-L	08/02/88	10.00	11/15/88	37.00	11/15/88	CAL
Weyerhauser Co.	Longview	WA	M45EC1-L	08/02/88	8.50	11/15/88	21.00	11/15/88	CAL
Weyerhauser Co.	New Bern	NC	M6EC	08/13/88	44.00	12/06/88	180.00	12/06/88	CAL
Weyerhauser Co.	Plymouth	NC	M86ECO	02/13/89	320.00	04/19/89	4000.00	04/19/89	CAL
Weyerhauser Co.	Rothchild	WI	M29EC	08/12/88	12.00	12/19/88	24.00	12/19/88	CAL
Weyerhauser Co.	Rothchild	WI	M29EC	08/12/88	12.00	06/28/89	18.00	06/28/89	CAL

A-2. TCDD/TCDF CONCENTRATION DATA (CONTINUED)

MATRIX=EFFLUENT (ppq)

Company	City	State	Sample ID	Sample Date	TCDD	TCDD Date	TCDF	TCDF Date	Lab
Mead Corporation	Escanaba	MI	ML802	12/15/87	17.00	08/08/88	50.80	08/08/88	WSU
Mead Corporation	Kingsport	TN	M73EC	06/06/88	6.00	11/04/88	44.00	11/04/88	CAL
Nekoosa Papers, Inc.	Nekoosa & Port Edwards	WI	M77EC	06/17/88	40.00	11/04/88	320.00	11/04/88	CAL
Nekoosa Papers, Inc.	Ashdown	AR	M20EC	10/08/88	41.00	02/16/89	94.00	02/16/89	CAL
Penntech Papers, Inc.	Johnsonburg	PA	M57EAC	08/01/88	6.80	12/19/88	14.00	12/19/88	CAL
Penntech Papers, Inc.	Johnsonburg	PA	M57EBC	08/01/88	9.70	12/19/88	65.00	12/19/88	CAL
Pope & Talbot, Inc.	Halsey	OR	M19EC	06/27/88	30.00	11/04/88	82.00	11/04/88	CAL
Potlatch Corp.	Cloquet	MN	M38ECO	09/24/88	24.00	01/26/89	46.00	01/26/89	CAL
Potlatch Corp.	Lewiston	ID	M56EC	07/26/88	71.00	11/15/88	360.00	11/15/88	CAL
Potlatch Corp.	Lewiston	ID	M56EC1	07/26/88	79.00	11/15/88	320.00	11/15/88	CAL
Potlatch Corp.	McGhee	AR	M18EC	07/15/88	40.00	11/22/88	100.00	11/22/88	CAL
Alabama River Pulp	Claiborne	AL	M21EC	06/07/88	41.00	11/04/88	250.00	11/04/88	CAL
Alabama River Pulp	Claiborne	AL	M21EC1	06/07/88	40.00	11/04/88	250.00	11/04/88	CAL
Alabama River Pulp	Claiborne	AL	M21EC2	06/07/88	46.00	01/03/89	210.00	01/03/89	CAL
Appleton Papers, Inc.	Roaring Springs	PA	M13EDO	06/26/88	11.00	11/03/88	18.00	11/03/88	CAL
Boise Cascade Corp.	Jackson	AL	M65EC	06/17/88	95.00	01/26/89	540.00	01/26/89	CAL
Boise Cascade Corp.	Jackson	AL	M65EC1	06/17/88	120.00	01/26/89	630.00	01/26/89	CAL
Boise Cascade Corp.	Deridder	LA	M58EC	06/10/88	9.20	11/04/88	44.00	11/04/88	CAL
Boise Cascade Corp.	St. Helens	OR	M76ECO	02/24/89	22.00	04/19/89	100.00	04/19/89	CAL
Boise Cascade Corp.	Rumford	ME	M82EC	06/02/88	120.00	11/04/88	570.00	11/04/88	CAL
Boise Cascade Corp.	Wallula	WA	M66EC	07/15/88	360.00	12/19/88	7500.00	12/19/88	CAL
Boise Cascade Corp.	International Falls	MN	DE020922	.	111.00	01/16/87	2180.00	02/12/87	WSU
Boise Cascade Corp.	International Falls	MN	DE020922	.	150.00	02/12/87	.	.	WSU
Boise Cascade Corp.	International Falls	MN	DE020922	.	111.00	02/12/87	.	.	WSU
Bowater Corp.	Catawba	SC	M23EC	06/17/88	24.00	11/04/88	42.00	11/04/88	CAL
Bowater Corp.	Calhoun	TN	M75EC	06/24/88	6.80	12/19/88	5.50	12/19/88	CAL
Brunswick Pulp and Paper	Brunswick	GA	M87EC	08/26/88	30.00	12/06/88	68.00	12/06/88	CAL
Brunswick Pulp and Paper	Brunswick	GA	M87EC1	08/26/88	30.00	12/06/88	50.00	12/06/88	CAL
Buckeye Cellulose	Perry	FL	M91ECO	.	27.00	11/03/88	80.00	11/03/88	CAL
Buckeye Cellulose	Oglethorpe	GA	M22EC10	07/23/88	12.00	11/03/88	26.00	11/03/88	CAL
Champion International	Lufkin	TX	DF024512	.	7.50	07/09/87	6.90	07/09/87	WSU
Champion International	Lufkin	TX	DF024512	.	7.20	09/30/87	6.70	09/30/87	WSU
Champion International	Lufkin	TX	DF024512	.	9.10	11/16/87	.	.	WSU
Champion International	Courtland	AL	M40EC	06/24/88	77.00	11/04/88	340.00	11/04/88	CAL
Champion International	Quinnesec	MI	Q14E	12/15/87	9.00	10/03/88	66.00	10/03/88	WSU
Champion International	Cantonment	FL	CP1000	01/15/88	11.00	11/03/88	38.00	11/03/88	CAL
Champion International	Houston	TX	M15EC	10/07/88	.	01/03/89	86.00	01/03/89	CAL
Champion International	Houston	TX	M15EC1	10/07/88	.	. .	11.00	01/13/89	CAL
Champion International	Houston	TX	M15EC2	10/07/88	5.50	05/31/89	5.80	05/31/89	CAL
Champion International	Canton	NC	M47G100-500	04/21/88	15.00	05/31/89	7.20	05/31/89	CAL
Chesapeake Corp.	West Point	VA	M74EC140	12/04/88	16.00	04/19/89	96.00	04/19/89	CAL
Container Corp. of America	Brewton	AL	M67EC	07/01/88	6.50	11/04/88	10.00	11/04/88	CAL
Pentair, Inc.	Park Falls	WI	M25EC	07/04/88	5.40	11/22/88	4.80	11/22/88	CAL
Federal Paper Board Co.	Augusta	GA	M83EC	06/10/88	16.00	12/06/88	47.00	12/06/88	CAL
Federal Paper Board Co.	Riegelwood	NC	M16EC	12/13/88	28.00	05/31/89	61.00	01/26/89	CAL
Finch, Pruyn & Co., Inc.	Glens Falls	NY	M41EC	01/13/89	7.90	06/28/89	2.90	06/28/89	CAL
Georgia-Pacific Corp.	Bellingham	WA	M60EC1	07/22/88	5.30	06/28/89	840.00	06/28/89	CAL
Georgia-Pacific Corp.	Crossett	AR	M68EC	09/02/88	96.00	12/19/88	370.00	12/19/88	CAL
Georgia-Pacific Corp.	Palatka	FL	M24EC	07/05/88	16.00	11/15/88	38.00	11/15/88	CAL
Georgia-Pacific Corp.	Woodland	ME	M17EC	07/22/88	6.80	11/04/88	25.00	11/04/88	CAL
Georgia-Pacific Corp.	Zachary	LA	M1EC	07/21/88	190.00	11/22/88	.	11/22/88	CAL
Georgia-Pacific Corp.	Zachary	LA	M1EC	07/21/88	160.00	05/31/89	3000.00	05/31/89	CAL
P.H. Glatfelter Co.	Spring Grove	PA	M64EC20	10/28/88	8.40	01/26/89	26.00	01/26/89	CAL

A-2. TCDD/TCDF CONCENTRATION DATA (CONTINUED)

MATRIX=SLUDGE (ppt)

Company	City	State	Sample ID	Sample Date	TCDD	TCDD Date	TCDF	TCDF Date	Lab
Temple-Eastex, Inc.	Evadale	TX	M3S3	07/28/88	16.00	12/06/88	49.00	12/06/88	CAL
Union Camp Corp.	Eastover	SC	M93SC	07/22/88	6.90	01/03/89	13.00	01/03/89	CAL
Union Camp Corp.	Franklin	VA	UCF10	05/08/88	3.60	11/03/88	6.00	11/03/88	CAL
Westvaco Corp.	Covington	VA	M28SC	07/19/88	119.00	12/19/88	799.00	12/19/88	CAL
Westvaco Corp.	Luke	MD	M62SC	06/28/88	80.00	12/22/88	471.00	12/22/88	CAL
Westvaco Corp.	Wickliffe	KY	M78SC	07/23/88	9.40	12/22/88	46.00	12/22/88	CAL
Weyerhauser Co.	Cosmopolis	WA	M4SC1	08/06/88	12.00	06/29/89	61.00	06/29/89	CAL
Weyerhauser Co.	Longview	WA	M45SC-L	08/02/88	25.00	12/22/88	80.00	12/22/88	CAL
Weyerhauser Co.	Longview	WA	M45SC1-L	08/02/88	.	12/22/88	84.00	12/22/88	CAL
Weyerhauser Co.	Longview	WA	M45SC1-L	08/02/88	35.00	03/01/89	89.00	03/01/89	CAL
Weyerhauser Co.	New Bern	NC	M6SC	08/13/88	373.00	12/19/88	1920.00	12/19/88	CAL
Weyerhauser Co.	New Bern	NC	M6SC1	08/13/88	213.00	12/19/88	1600.00	12/19/88	CAL
Weyerhauser Co.	Plymouth	NC	M86SCO	02/13/89	1390.00	04/19/89	17100.00	04/19/89	CAL
Weyerhauser Co.	Rothchild	WI	M29SC	08/12/88	58.00	12/19/88	150.00	12/19/88	CAL

MATRIX=SLURRY (ppq)

Company	City	State	Sample ID	Sample Date	TCDD	TCDD Date	TCDF	TCDF Date	Lab
Wilamette Industries	Hawesville	KY	M63SAC	10/28/88	83.00	01/26/89	380.00	01/26/89	CAL
Wilamette Industries	Hawesville	KY	M63SBC	10/28/88	52.00	01/26/89	210.00	01/26/89	CAL
Badger Paper Mills, Inc.	Peshtigo	WI	M46SC	07/22/88	36.00	12/06/88	1800.00	12/06/88	CAL
Kimberly-Clark Corp.	Coosa Pines	AL	M36SC	08/26/88	3800.00	12/06/88	9200.00	12/06/88	CAL
Gilman Paper Co.	St. Marys	GA	M55SC	09/02/88	220.00	12/06/88	610.00	12/06/88	CAL
Hammermill Paper Co.	Selma	AL	M88SC	06/26/88	680.00	12/06/88	2900.00	12/06/88	CAL
James River Corp.	Butler	AL	M96SC	06/16/88	330.00	12/06/88	1100.00	12/06/88	CAL
Boise Cascade Corp.	Deridder	LA	M58SC	06/10/88	280.00	12/06/88	440.00	12/06/88	CAL
Bowater Corp.	Catawba	SC	M23SC	06/17/88	620.00	12/06/88	880.00	12/06/88	CAL
Bowater Corp.	Calhoun	TN	M75SC	06/24/88	.	12/22/88	17000.00	12/22/88	CAL
Bowater Corp.	Calhoun	TN	M75SC	06/24/88	4500.00	02/14/89	14000.00	02/14/89	CAL
Federal Paper Board Co.	Augusta	GA	M83SC	06/10/88	680.00	01/03/89	1400.00	01/03/89	CAL
Georgia-Pacific Corp.	Crosset	AR	M68SAC1	09/02/88	.	12/22/88	740.00	12/22/88	CAL
Georgia-Pacific Corp.	Crosset	AR	M68SAC1	09/02/88	190.00	02/14/89	710.00	02/14/89	CAL
Georgia-Pacific Corp.	Palatka	FL	M24SC	07/05/88	92.00	12/06/88	410.00	12/06/88	CAL
Proctor & Gamble Co.	Mehoopany	PA	M42SAC	07/06/88	6.00	06/29/89	6.00	06/29/89	CAL
Stone Container Corp.	Missoula	MT	M27SC	07/12/88	55.00	12/06/88	150.00	12/06/88	CAL

A-2. TCDD/TCDF CONCENTRATION DATA (CONTINUED)

MATRIX-EFFLUENT (ppq)

Company	City	State	Sample ID	Sample Date	TCDD	TCDD Date	TCDF	TCDF Date	Lab
Gaylord Container Corp.	Erie	CA	M106EC	10/15/88	49.00	01/03/89	800.00	01/03/89	CAL
Wilamette Industries	Hawesville	KY	M63EC	10/28/88	11.00	01/03/89	8.00	01/03/89	CAL
Alaska Pulp Co.	Sitka	AK	M5EC-1	08/27/88	7.70	06/28/89	32.00	06/28/89	CAL
Badger Paper Mills, Inc.	Peshtigo	WI	M46EAC	07/22/88	9.80	11/15/88	280.00	11/15/88	CAL
Badger Paper Mills, Inc.	Peshtigo	WI	M46EAC	07/22/88	6.40	06/28/89	170.00	06/28/89	CAL
Badger Paper Mills, Inc.	Peshtigo	WI	M46EBC	07/22/88	4.50	11/15/88	110.00	11/15/88	CAL
Badger Paper Mills, Inc.	Peshtigo	WI	M46EBC	07/21/88	5.30	06/28/89	130.00	06/28/89	CAL
Kimberly-Clark Corp.	Coosa Pines	AL	M36EC	08/26/88	35.00	11/15/88	74.00	11/15/88	CAL
Lincoln Pulp and Paper	Lincoln	ME	M11EC	11/19/88	32.00	01/26/89	130.00	01/26/89	CAL
Wausau Paper Mills Co.	Brokaw	WI	M54EC	07/22/88	4.20	11/15/88	14.00	11/15/88	CAL
Wausau Paper Mills Co.	Brokaw	WI	M54EC	07/22/88	4.90	06/28/89	2.10	06/28/89	CAL
Gilman Paper Co.	St. Marys	GA	M55EC	09/02/88	6.50	11/15/88	17.00	11/15/88	CAL
Gulf States Paper Corp.	Demopolis	AL	M101EC	06/14/88	38.00	11/15/88	110.00	11/15/88	CAL
Hammermill Paper Co.	Erie	PA	M103ECX	06/19/88	24.00	11/04/88	68.00	11/04/88	CAL
Hammermill Paper Co.	Selma	AL	M88EC	06/26/88	81.00	11/15/88	310.00	11/15/88	CAL
International Paper Co.	Bastrop	LA	M85EC	06/20/88	330.00	11/04/88	1600.00	11/04/88	CAL
International Paper Co.	Georgetown	SC	M70EC	07/16/88	640.00	11/22/88	1600.00	11/22/88	CAL
International Paper Co.	Georgetown	SC	M70EC1	07/16/88	490.00	11/22/88	1500.00	11/22/88	CAL
International Paper Co.	Jay	ME	RG186388	.	88.10	07/07/87	447.00	07/07/87	WSU
International Paper Co.	Jay	ME	RG186388	.	95.30	09/30/87	441.00	09/30/87	WSU
International Paper Co.	Jay	ME	RG186388A	.	80.40	08/26/87	359.00	08/26/87	WSU
International Paper Co.	Mobile	AL	M71EC	10/24/88	.	01/03/89	850.00	01/03/89	CAL
International Paper Co.	Mobile	AL	M71ECD	10/24/88	100.00	05/31/89	490.00	05/31/89	CAL
International Paper Co.	Moss Point	MS	M34EC	06/07/88	160.00	11/15/88	920.00	11/15/88	CAL
International Paper Co.	Natchez	MS	M97EC	08/12/88	38.00	11/03/88	220.00	11/03/88	CAL
International Paper Co.	Pine Bluff	AR	M51EC	06/17/88	110.00	11/04/88	1100.00	11/04/88	CAL
International Paper Co.	Texarkana	TX	M99EC	08/06/88	13.00	11/22/88	43.00	11/22/88	CAL
International Paper Co.	Texarkana	TX	M99EC1	08/06/88	18.00	11/22/88	44.00	11/22/88	CAL
International Paper Co.	Ticonderoga	NY	M9EC	06/24/88	18.00	11/04/88	150.00	11/04/88	CAL
International Paper Co.	Ticonderoga	NY	M9EC1	06/24/88	24.00	11/04/88	160.00	11/04/88	CAL
ITT-Rayonier, Inc.	Fernandina Beach	FL	M90EC	07/06/88	7.00	06/28/89	35.00	06/28/89	CAL
ITT-Rayonier, Inc.	Hoquiam	WA	M33EC	07/09/88	23.00	06/28/89	8.60	06/28/89	CAL
ITT-Rayonier, Inc.	Jesup	GA	M84EBC	07/24/88	23.00	11/22/88	16.00	11/22/88	CAL
ITT-Rayonier, Inc.	Jesup	GA	M84EAC	07/24/88	24.00	11/22/88	.	11/22/88	CAL
ITT-Rayonier, Inc.	Jesup	GA	M84EAC1	07/24/88	11.00	05/31/89	4.20	05/31/89	CAL
ITT-Rayonier, Inc.	Port Angeles	WA	M12EC	07/27/88	22.00	06/28/89	36.00	06/28/89	CAL
James River Corp.	Berlin	NH	M89EC	08/19/88	59.00	12/06/88	1200.00	12/06/88	CAL
James River Corp.	Camas	WA	M32EC	.	.	05/31/89	160.00	05/31/89	CAL
James River Corp.	Clatskanie	OR	86374645	.	15.70	07/09/87	133.00	07/09/87	WSU
James River Corp.	Clatskanie	OR	86374645	.	14.50	11/16/87	110.00	09/30/87	WSU
James River Corp.	Green Bay	WI	M72EBC	.	8.50	12/06/88	29.00	12/06/88	CAL
James River Corp.	Green Bay	WI	M72EAC	.	11.00	12/06/88	61.00	12/06/88	CAL
James River Corp.	Green Bay	WI	M72EAC	.	19.00	06/28/89	72.00	06/28/89	CAL
James River Corp.	Green Bay	WI	M72EAC1	.	15.00	06/28/89	54.00	06/28/89	CAL
James River Corp.	Old Town	ME	M8EC	.	39.00	11/15/88	130.00	11/15/88	CAL
James River Corp.	St. Francesville	LA	M52EC	.	82.00	02/16/89	320.00	02/16/89	CAL
James River Corp.	Butler	AL	M96EC	06/16/88	23.00	11/04/88	72.00	11/04/88	CAL
Leaf River Forest Products	New Augusta	MS	M35SEC30	02/27/88	200.00	02/16/89	410.00	02/16/89	CAL
Longview Fibre Co.	Longview	WA	M53EC	06/29/88	*4.60	12/06/88	57.00	12/06/88	CAL
Ketchikan Pulp & Paper Co.	Ketchikan	AK	M31EAC	08/15/88	6.70	06/28/89	5.30	06/28/89	CAL
Ketchikan Pulp & Paper Co.	Ketchikan	AK	M31EBC	08/15/88	15.00	06/28/89	7.20	06/28/89	CAL
Louisiana Pacific Corp.	Samoa	CA	M70EC10	11/20/88	.	01/26/89	320.00	01/26/89	CAL
[illegible]siana Pacific Corp.	Samoa	CA	M70EC10D	11/20/88	67.00	05/31/89	170.00	05/31/89	CAL
Corporation	Chillicothe	OH	DE02601	10/18/86	3.00	.	11.00	.	WSU

A-3. TCDD/TCDF FIELD DUPLICATES

MATRIX=PULP (ppt)

Company	City	State	Sample ID	Sample Date	TCDD	TCDD Date	TCDF	TCDF Date	Lab
International Paper Co.	Bastrop	LA	M85PAC	06/20/88	5.10	12/16/88	22.00	12/16/88	WSU
International Paper Co.	Bastrop	LA	M85PAC1	06/20/88	5.70	12/16/88	23.00	12/16/88	WSU
International Paper Co.	Georgetown	SC	M70PAC	07/16/88	9.20	11/04/88	38.00	11/04/88	WSU
International Paper Co.	Georgetown	SC	M70PAC1	07/16/88	10.00	11/04/88	41.00	11/04/88	WSU
International Paper Co.	Georgetown	SC	M70PCC	07/16/88	17.00	12/16/88	55.00	12/16/88	WSU
International Paper Co.	Georgetown	SC	M70PCC1	07/16/88	16.00	12/16/88	52.00	12/16/88	WSU
Leaf River Forest Products	New Augusta	MS	M35DPC60	02/27/88	14.00	02/17/89	23.00	02/17/89	CAL
Leaf River Forest Products	New Augusta	MS	M35SPC60	02/27/88	15.00	02/17/89	35.00	02/17/89	CAL
Mead Corporation	Escanaba	MI	MP105	12/15/87	18.00	03/09/88	68.00	03/09/88	CAL
Mead Corporation	Escanaba	MI	MP106	12/15/87	15.00	03/21/88	39.00	03/21/88	CAL
Potlatch Corp.	Lewiston	ID	M56PC	07/26/88	25.00	12/02/88	153.00	12/02/88	WSU
Potlatch Corp.	Lewiston	ID	M56PC1	07/26/88	27.00	12/02/88	147.00	12/02/88	WSU
Alabama River Pulp	Claiborne	AL	M21PC	06/07/88	3.90	11/11/88	97.00	11/11/88	WSU
Alabama River Pulp	Claiborne	AL	M21PC1	06/07/88	3.80	11/11/88	98.00	11/11/88	WSU
Boise Cascade Corp.	Jackson	AL	M65PC	06/17/88	11.00	11/11/88	104.00	11/11/88	WSU
Boise Cascade Corp.	Jackson	AL	M65PC1	06/17/88	9.10	12/23/88	71.00	12/23/88	WSU
Brunswick Pulp and Paper	Brunswick	GA	M87PAC	08/26/88	6.30	11/25/88	8.00	11/25/88	WSU
Brunswick Pulp and Paper	Brunswick	GA	M87PAC1	08/26/88	6.10	11/25/88	9.40	11/25/88	WSU
Brunswick Pulp and Paper	Brunswick	GA	M87PBC	08/26/88	1.90	11/25/88	3.50	11/25/88	WSU
Brunswick Pulp and Paper	Brunswick	GA	M87PBC1	08/26/88	1.60	11/25/88	2.90	11/25/88	WSU
Champion International	Quinnesec	MI	Q7P	12/15/87	7.70	03/09/88	50.00	03/09/88	CAL
Champion International	Quinnesec	MI	Q9P	12/15/87	7.80	03/09/88	45.00	03/09/88	CAL
Champion International	Cantonment	FL	CPS300	01/15/88	2.00	09/30/88	2.20	09/30/88	WSU
Champion International	Cantonment	FL	CPS300	01/15/88	2.00	03/21/88	0.90	03/21/88	CAL
Champion International	Cantonment	FL	CPS302	01/15/88	4.90	03/21/88	1.10	03/21/88	CAL
Champion International	Canton	NC	M47C100-500	04/21/88	6.50	07/01/88	11.00	07/01/88	WSU
Champion International	Canton	NC	M47C100-500Q	04/21/88	4.60	10/06/88	5.50	10/06/88	WSU
Georgia-Pacific Corp.	Bellingham	WA	M60PC	07/22/88	2.60	12/09/88	449.00	12/09/88	WSU
Georgia-Pacific Corp.	Bellingham	WA	M60PC1	07/22/88	3.50	06/19/89	409.00	06/19/89	CAL
Scott Paper Co.	Hinckley	ME	M61PCB	06/28/88	8.50	11/18/88	37.00	11/18/88	WSU
Scott Paper Co.	Hinckley	ME	M61PCB1	06/28/88	7.90	11/18/88	35.00	11/18/88	WSU
Simpson Paper Co.	Pasadena	TX	M2PAC	10/08/88	14.00	12/23/88	48.00	12/23/88	WSU
Simpson Paper Co.	Pasadena	TX	M2PAC1	10/08/88	18.00	12/23/88	66.00	12/23/88	WSU
Weyerhauser Co.	Cosmopolis	WA	M4PAC	08/06/88	1.00	12/09/88	6.30	12/09/88	WSU
Weyerhauser Co.	Cosmopolis	WA	M4PAC1	08/06/88	.	12/09/88	6.40	12/09/88	WSU
Weyerhauser Co.	Cosmopolis	WA	M4PBC	08/06/88	0.30	12/30/88	3.10	12/30/88	WSU
Weyerhauser Co.	Cosmopolis	WA	M4PBC1	08/06/88	0.30	12/30/88	2.90	12/30/88	WSU
Weyerhauser Co.	Longview	WA	M45PAC	08/02/88	1.70	12/02/88	2.80	12/02/88	WSU
Weyerhauser Co.	Longview	WA	M45PAC1	08/02/88	1.60	12/02/88	2.80	12/02/88	WSU

A-3. TCDD/TCDF FIELD DUPLICATES (CONTINUED)

MATRIX=SLUDGE (ppt)

Company	City	State	Sample ID	Sample Date	TCDD	TCDD Date	TCDF	TCDF Date	Lab
International Paper Co.	Texarkana	TX	M99SC	08/06/88	71.00	01/03/89	1000.00	01/03/89	CAL
International Paper Co.	Texarkana	TX	M99SC1	08/06/88	.	01/03/89	600.00	01/03/89	CAL
Alabama River Pulp	Claiborne	AL	M21SC	06/07/88	81.00	12/06/88	373.00	12/06/88	CAL
Alabama River Pulp	Claiborne	AL	M21SC1	06/07/88	73.00	12/06/88	393.00	12/06/88	CAL
Alabama River Pulp	Claiborne	AL	M21SC2	06/07/88	68.00	01/26/89	342.00	01/26/89	CAL
Boise Cascade Corp.	Jackson	AL	M65SC	06/17/88	18.00	12/22/88	147.00	12/22/88	CAL
Boise Cascade Corp.	Jackson	AL	M65SC1	06/17/88	18.00	12/22/88	169.00	12/22/88	CAL
Champion International	Canton	NC	M47J100-500	04/21/88	175.00	07/01/88	.	07/01/88	WSU
Champion International	Canton	NC	M47J100-500Q	04/21/88	172.00	10/06/88	260.00	10/06/88	WSU
Federal Paper Board Co.	Riegelwood	NC	M16SC	12/13/88	3.80	04/19/89	5.20	04/19/89	CAL
Federal Paper Board Co.	Riegelwood	NC	M16SCO	12/13/88	2.90	04/19/89	3.30	04/19/89	CAL
Scott Paper Co.	Hinckley	ME	M61SCA	06/28/88	33.00	12/06/88	106.00	12/06/88	CAL
Scott Paper Co.	Hinckley	ME	M61SCA1	06/28/88	39.00	12/06/88	149.00	12/06/88	CAL
Simpson Paper Co.	Tacoma	WA	M81SC	10/29/88	39.00	06/19/89	101.00	06/19/89	CAL
Simpson Paper Co.	Tacoma	WA	M81SC D	10/29/88	29.00	06/19/89	106.00	06/19/89	CAL
Weyerhauser Co.	Longview	WA	M45SC-L	08/02/88	25.00	12/22/88	80.00	12/22/88	CAL
Weyerhauser Co.	Longview	WA	M45SC1-L	08/02/88	.	12/22/88	84.00	12/22/88	CAL
Weyerhauser Co.	New Bern	NC	M6SC	08/13/88	373.00	12/19/88	1920.00	12/19/88	CAL
Weyerhauser Co.	New Bern	NC	M6SC1	08/13/88	213.00	12/19/88	1600.00	12/19/88	CAL

MATRIX=EFFLUENT (ppq)

Company	City	State	Sample ID	Sample Date	TCDD	TCDD Date	TCDF	TCDF Date	Lab
International Paper Co.	Georgetown	SC	M70EC	07/16/88	640.00	11/22/88	1600.00	11/22/88	CAL
International Paper Co.	Georgetown	SC	M70EC1	07/16/88	490.00	11/22/88	1500.00	11/22/88	CAL
International Paper Co.	Texarkana	TX	M99EC	08/06/88	13.00	11/22/88	43.00	11/22/88	CAL
International Paper Co.	Texarkana	TX	M99EC1	08/06/88	18.00	11/22/88	44.00	11/22/88	CAL
International Paper Co.	Ticonderoga	NY	M9EC	06/24/88	18.00	11/04/88	150.00	11/04/88	CAL
James River Corp.	Green Bay	WI	M72EAC	.	19.00	06/28/89	72.00	06/28/89	CAL
James River Corp.	Green Bay	WI	M72EAC1	.	15.00	06/28/89	54.00	06/28/89	CAL
Potlatch Corp.	Lewiston	ID	M56EC	07/26/88	71.00	11/15/88	360.00	11/15/88	CAL
Potlatch Corp.	Lewiston	ID	M56EC1	07/26/88	79.00	11/15/88	320.00	11/15/88	CAL
Alabama River Pulp	Claiborne	AL	M21EC	06/07/88	41.00	11/04/88	250.00	11/04/88	CAL
Alabama River Pulp	Claiborne	AL	M21EC1	06/07/88	40.00	11/04/88	250.00	11/04/88	CAL
Alabama River Pulp	Claiborne	AL	M21EC2	06/07/88	46.00	01/03/89	210.00	01/03/89	CAL
Boise Cascade Corp.	Jackson	AL	M65EC	06/17/88	95.00	01/26/89	540.00	01/26/89	CAL
Boise Cascade Corp.	Jackson	AL	M65EC1	06/17/88	120.00	01/26/89	630.00	01/26/89	CAL
Brunswick Pulp and Paper	Brunswick	GA	M87EC	08/26/88	30.00	12/06/88	68.00	12/06/88	CAL
Brunswick Pulp and Paper	Brunswick	GA	M87EC1	08/26/88	30.00	12/06/88	50.00	12/06/88	CAL
Scott Paper Co.	Hinckley	ME	M61EC	06/28/88	16.00	12/19/88	63.00	12/19/88	CAL
Scott Paper Co.	Hinckley	ME	M61EC1	06/28/88	19.00	12/19/88	100.00	12/19/88	CAL
Simpson Paper Co.	Tacoma	WA	M81EC	10/29/88	.	05/31/89	26.00	05/31/89	CAL
Simpson Paper Co.	Tacoma	WA	M81EC1	10/29/88	.	05/31/89	22.00	05/31/89	CAL
Weyerhauser Co.	Longview	WA	M45EC-L	08/02/88	10.00	11/15/88	37.00	11/15/88	CAL
Weyerhauser Co.	Longview	WA	M45EC1-L	08/02/88	8.50	11/15/88	21.00	11/15/88	CAL

A-4. TCDD/TCDF LAB DUPLICATES

MATRIX=PULP (ppt)

Company	City	State	Sample ID	Sample Date	TCDD	TCDD Date	TCDF	TCDF Date	Lab
International Paper Co.	Jay	ME	RG186367	.	55.70	04/21/87	181.00	04/21/87	WSU
International Paper Co.	Jay	ME	RG186367	.	46.70	08/19/87	183.00	08/19/87	WSU
International Paper Co.	Pine Bluff	AR	M51PAC	06/17/88	21.00	11/18/88	647.00	11/18/88	WSU
International Paper Co.	Pine Bluff	AR	M51PAC	06/17/88	23.00	11/18/88	661.00	11/18/88	WSU
International Paper Co.	Ticonderoga	NY	M9PAC	06/24/88	16.00	11/04/88	103.00	11/04/88	WSU
International Paper Co.	Ticonderoga	NY	M9PAC	06/24/88	17.00	11/04/88	108.00	11/04/88	WSU
James River Corp.	Clatskanie	OR	86374612	.	10.20	04/21/87	54.30	04/21/87	WSU
James River Corp.	Clatskanie	OR	86374612	.	11.00	08/19/87	64.40	08/19/87	WSU
James River Corp.	Clatskanie	OR	86374661	.	12.60	04/21/87	63.90	04/21/87	WSU
Longview Fibre Co.	Longview	WA	M53PAC	06/29/88	4.80	12/02/88	.	12/02/88	WSU
Longview Fibre Co.	Longview	WA	M53PAC	06/29/88	4.40	06/19/89	28.00	06/19/89	CAL
Longview Fibre Co.	Longview	WA	M53PAC D	06/29/88	4.70	06/19/89	26.00	06/19/89	CAL
Boise Cascade Corp.	St. Helens	OR	M76PC60	06/27/88	4.20	04/19/89	12.00	04/19/89	CAL
Boise Cascade Corp.	St. Helens	OR	M76PC600	02/24/89	4.40	04/19/89	11.00	04/19/89	CAL
Boise Cascade Corp.	International Falls	MN	DE020902	.	15.20	03/19/87	.	.	WSU
Boise Cascade Corp.	International Falls	MN	DE020902	.	16.30	04/21/87	333.00	04/21/87	WSU
Champion International	Lufkin	TX	DF024411	.	3.89	04/21/87	7.68	04/21/87	WSU
Champion International	Lufkin	TX	DF024411	.	3.99	08/19/87	7.90	08/19/87	WSU
Champion International	Cantonment	FL	CPH300	01/15/88	0.70	09/30/88	4.10	09/30/88	WSU
Champion International	Cantonment	FL	CPH300	01/15/88	1.00	03/21/88	0.70	03/21/88	CAL
Champion International	Cantonment	FL	CPS300	01/15/88	2.00	09/30/88	2.20	09/30/88	WSU
Champion International	Cantonment	FL	CPS300	01/15/88	2.00	03/21/88	0.90	03/21/88	CAL
Federal Paper Board Co.	Riegelwood	NC	M16PDC	12/13/88	3.20	01/17/89	1.30	01/17/89	WSU
Federal Paper Board Co.	Riegelwood	NC	M16PDC	12/13/88	3.30	01/17/89	1.50	01/17/89	WSU
P.H. Glatfelter Co.	Spring Grove	PA	M64PC50	10/28/88	3.90	01/12/89	13.00	01/12/89	CAL
P.H. Glatfelter Co.	Spring Grove	PA	M64PC50D	10/28/88	6.50	01/12/89	18.00	01/12/89	CAL
Scott Paper Co.	Muskegon	MI	M92PC	06/13/88	0.30	11/11/88	1.00	11/11/88	WSU
Scott Paper Co.	Muskegon	MI	M92PC	06/13/88	0.40	11/11/88	1.40	11/11/88	WSU
Union Camp Corp.	Franklin	VA	UCS600	05/08/88	5.20	11/03/88	5.70	11/03/88	CAL
Union Camp Corp.	Franklin	VA	UCS6000	05/08/88	5.40	11/03/88	6.90	11/03/88	CAL
Westvaco Corp.	Wickliffe	KY	M78PAC	07/23/88	12.00	12/09/88	55.00	12/09/88	WSU
Westvaco Corp.	Wickliffe	KY	M78PACD	07/23/88	11.00	12/09/88	54.00	12/09/88	WSU

FIGURE B-1

PULP TCDD

PROBABILITY PLOT: DETECTED VALUES ONLY

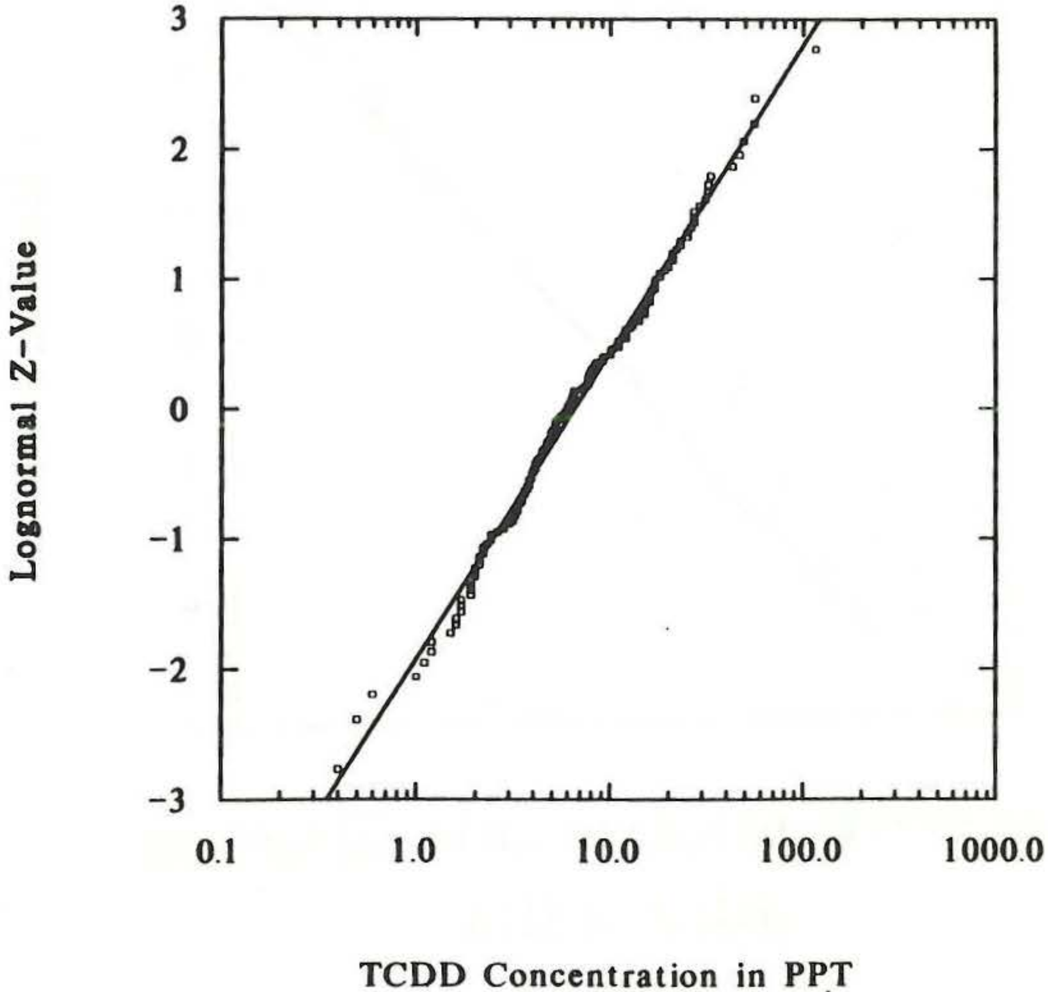


FIGURE B-2

PULP TCDF

PROBABILITY PLOT: DETECTED VALUES ONLY

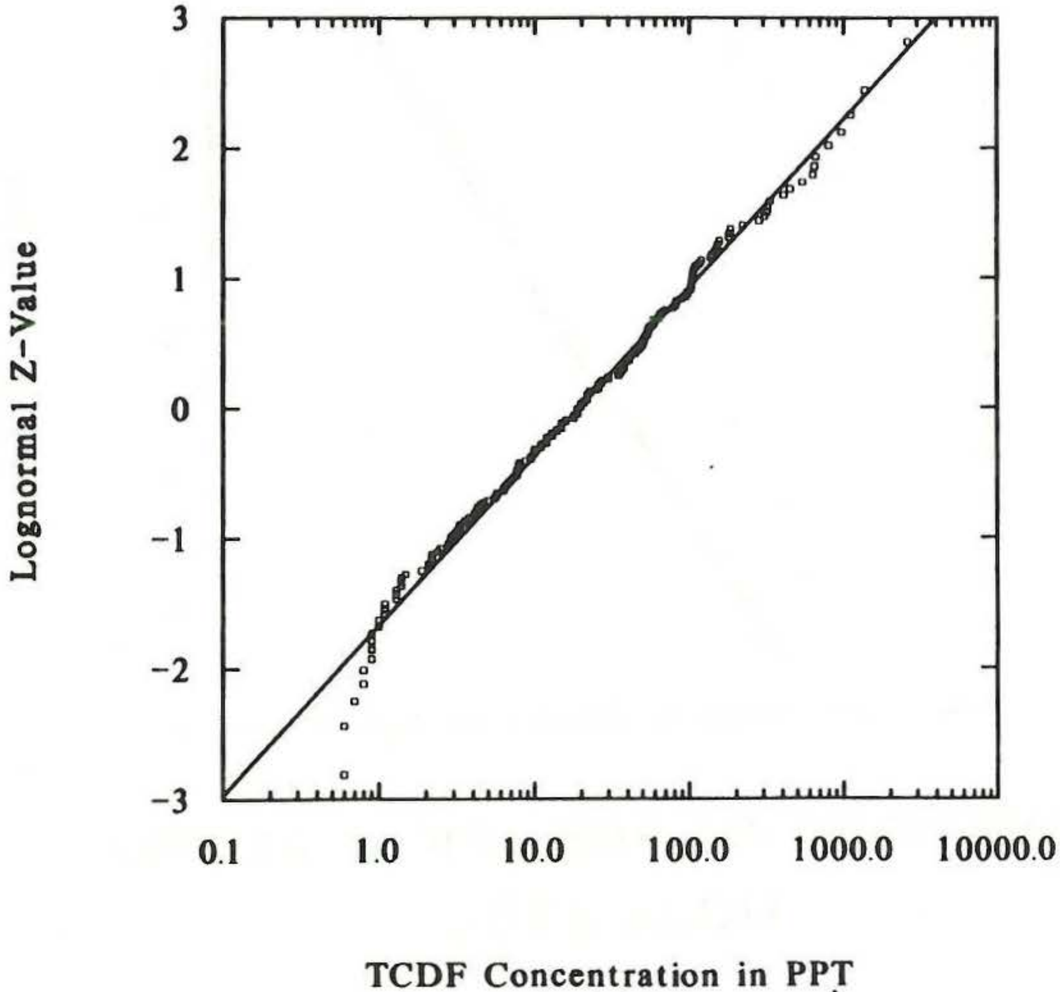


FIGURE B-3

SLUDGE TCDD

PROBABILITY PLOT: DETECTED VALUES ONLY

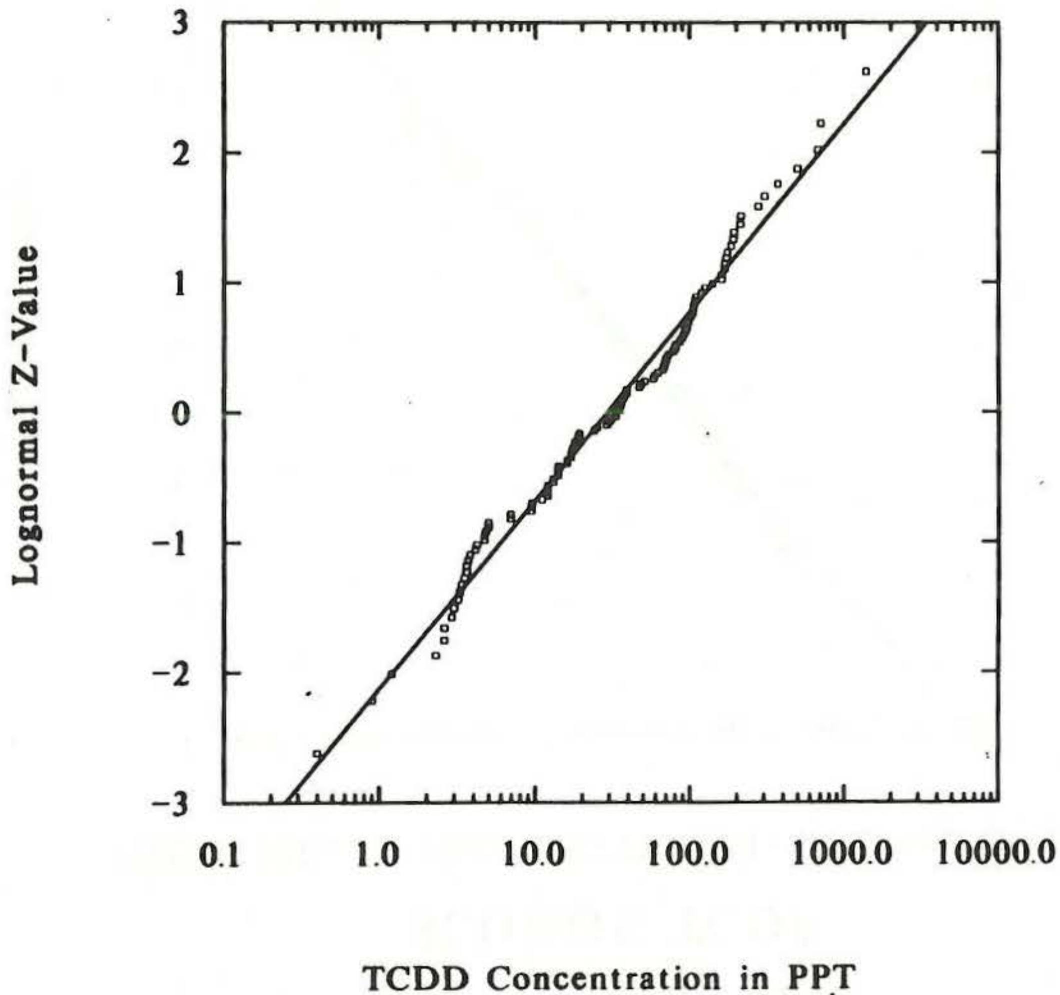


FIGURE B-4

SLUDGE TCDF

PROBABILITY PLOT: DETECTED VALUES ONLY

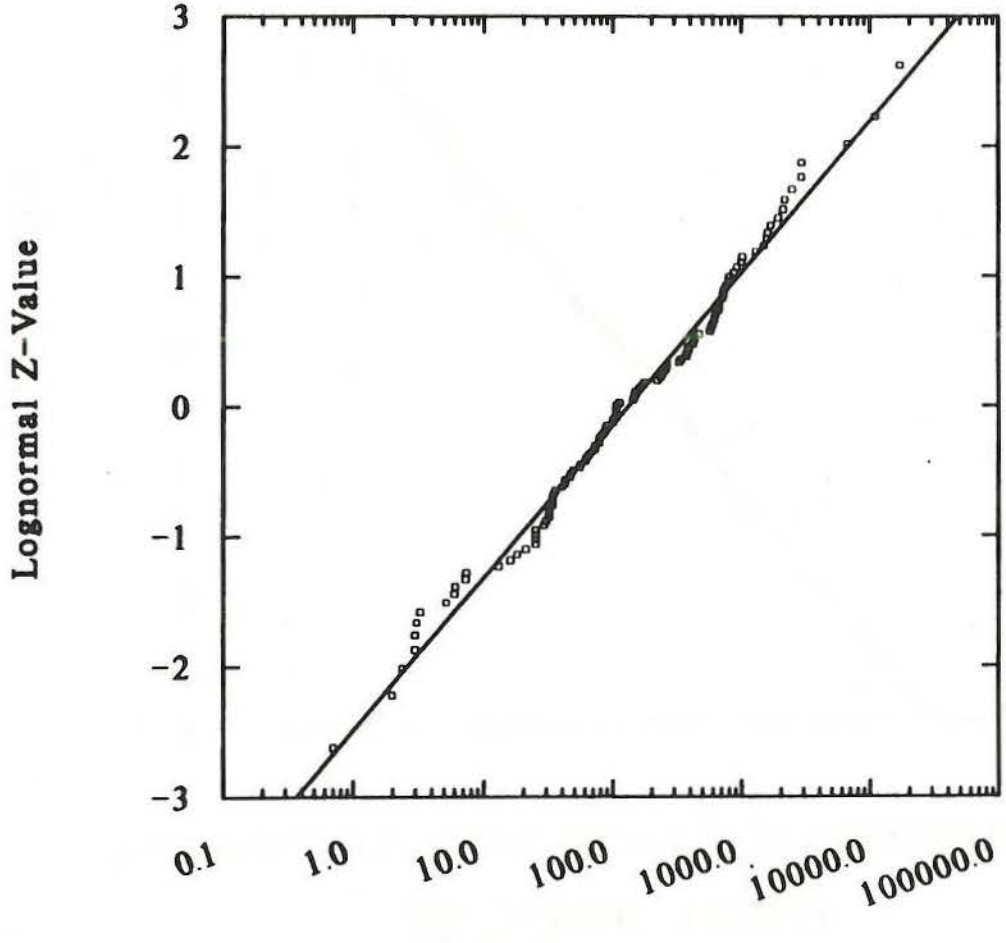


FIGURE B-5

EFFLUENT TCDD

PROBABILITY PLOT: DETECTED VALUES ONLY

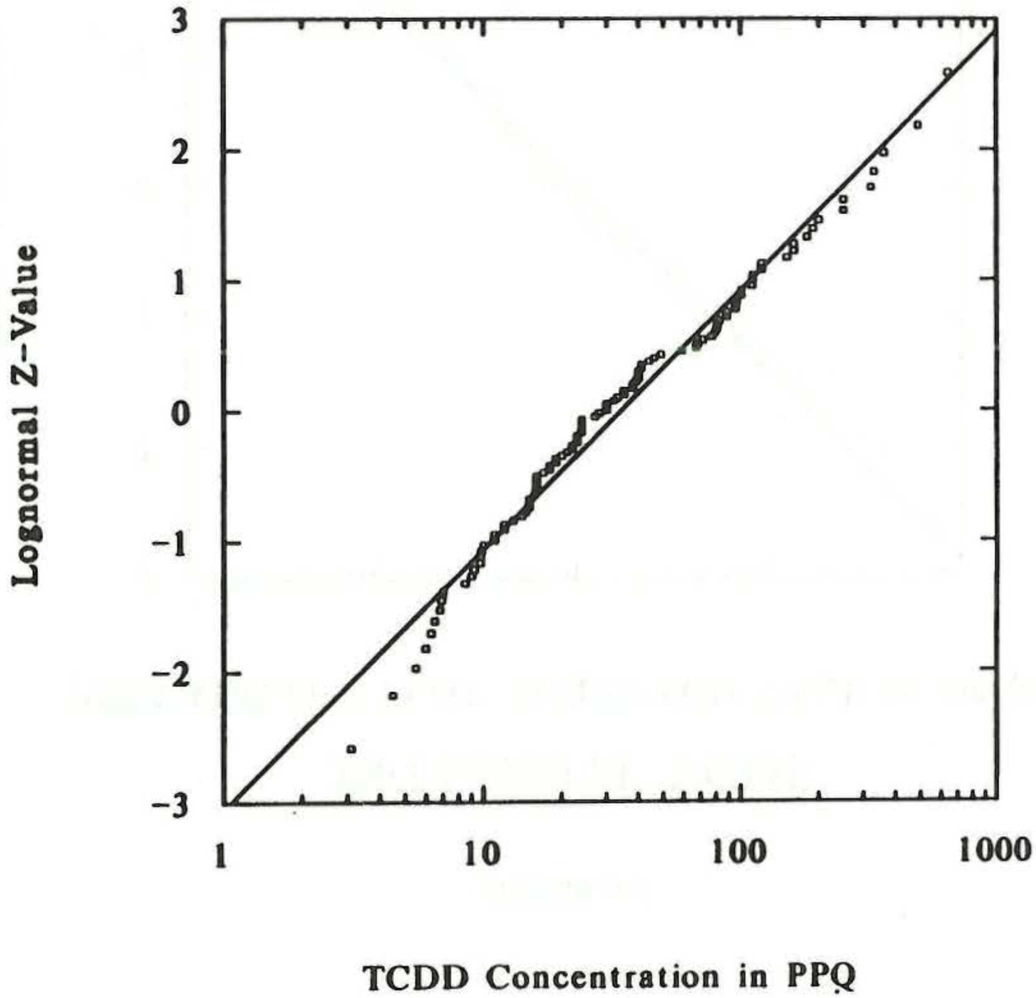


FIGURE B-6

EFFLUENT TCDF

PROBABILITY PLOT: DETECTED VALUES ONLY

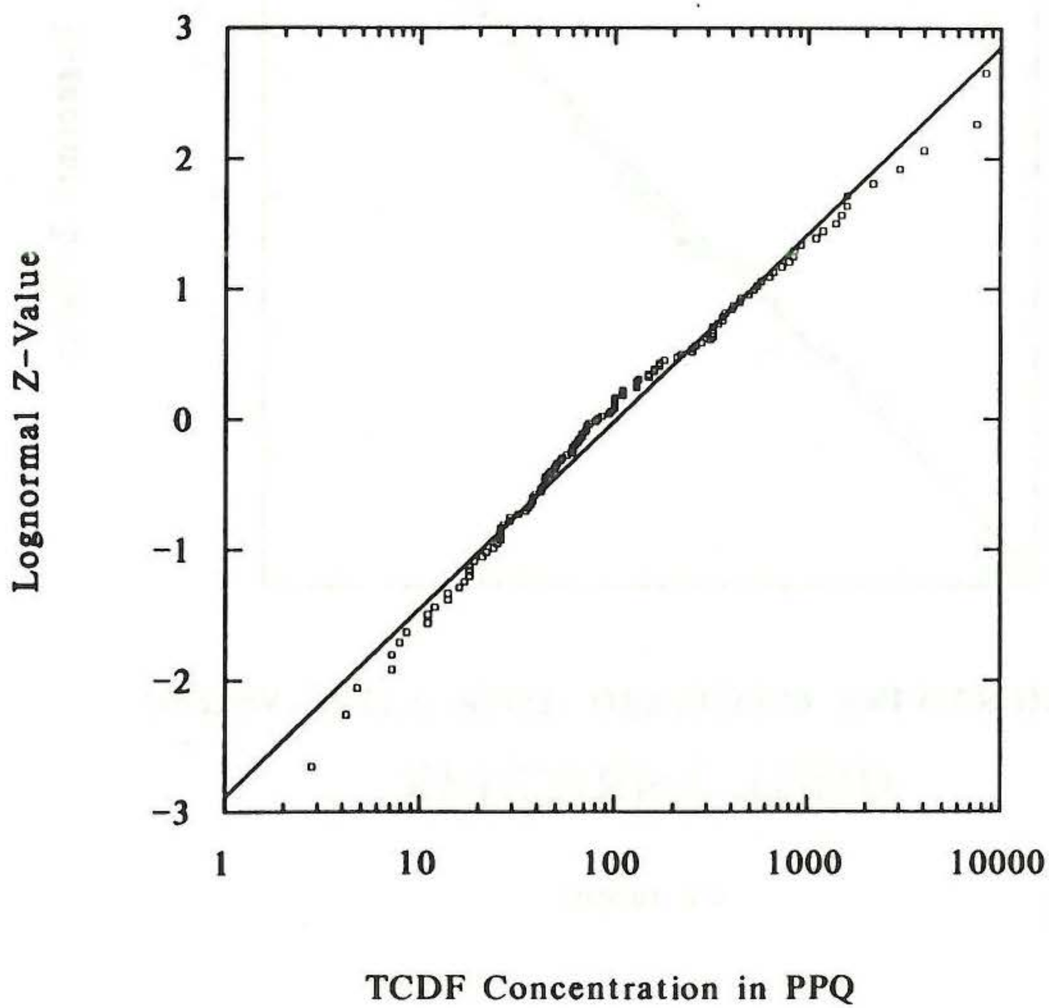


FIGURE B-7

PULP TCDD

PROBABILITY PLOT

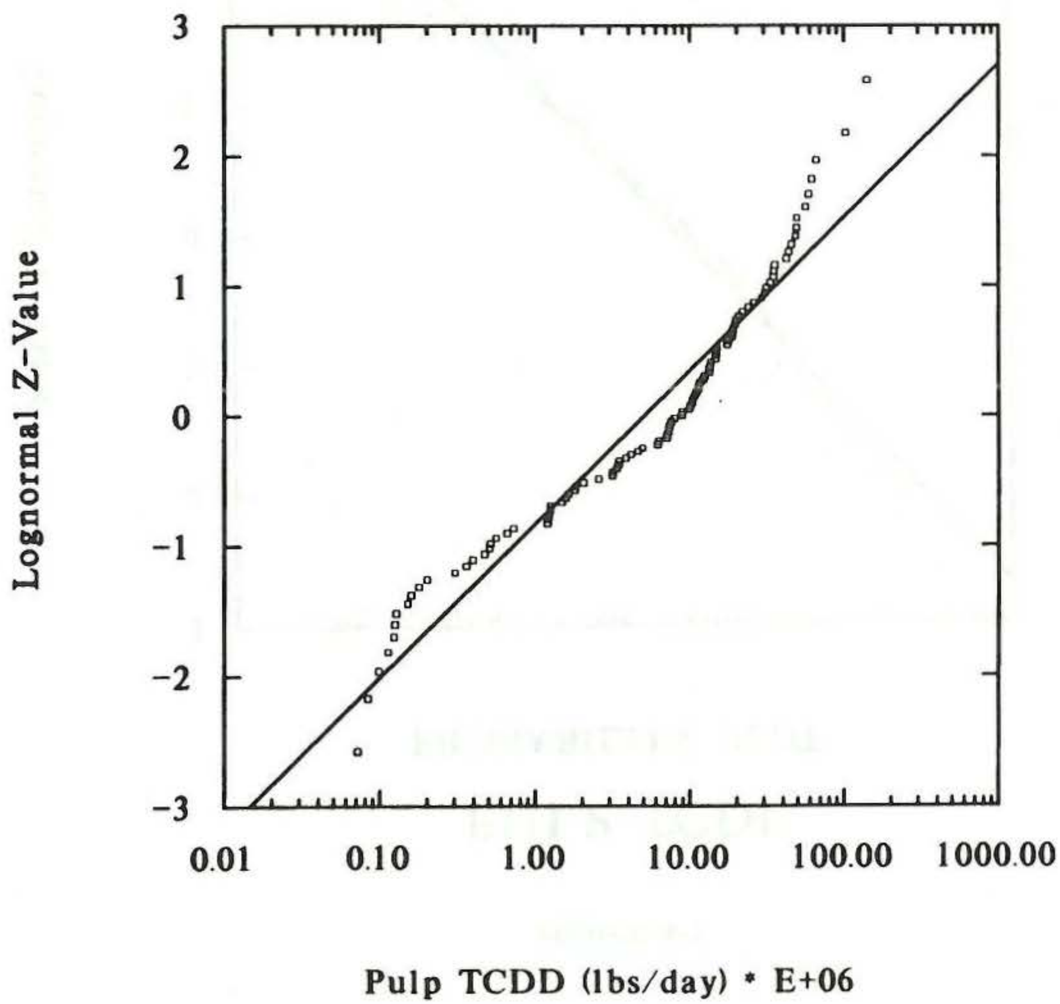


FIGURE B-8

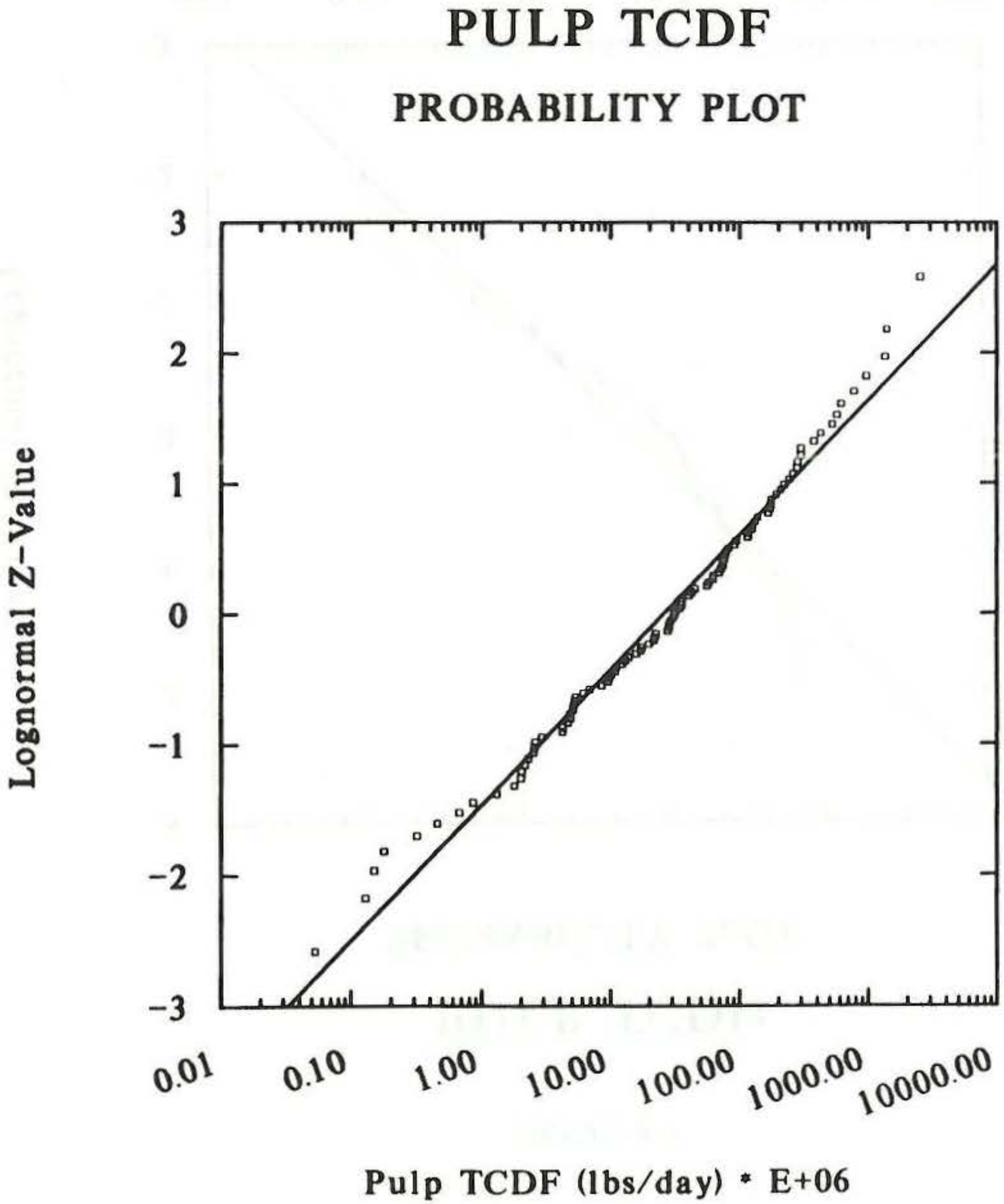

PULP TCDF
PROBABILITY PLOT
Lognormal Z-Value
3
2
1
0
-1
-2
-3
0.01
0.10
1.00
10.00
100.00
1000.00
10000.00
Pulp TCDF (lbs/day) * E+06

FIGURE B-9

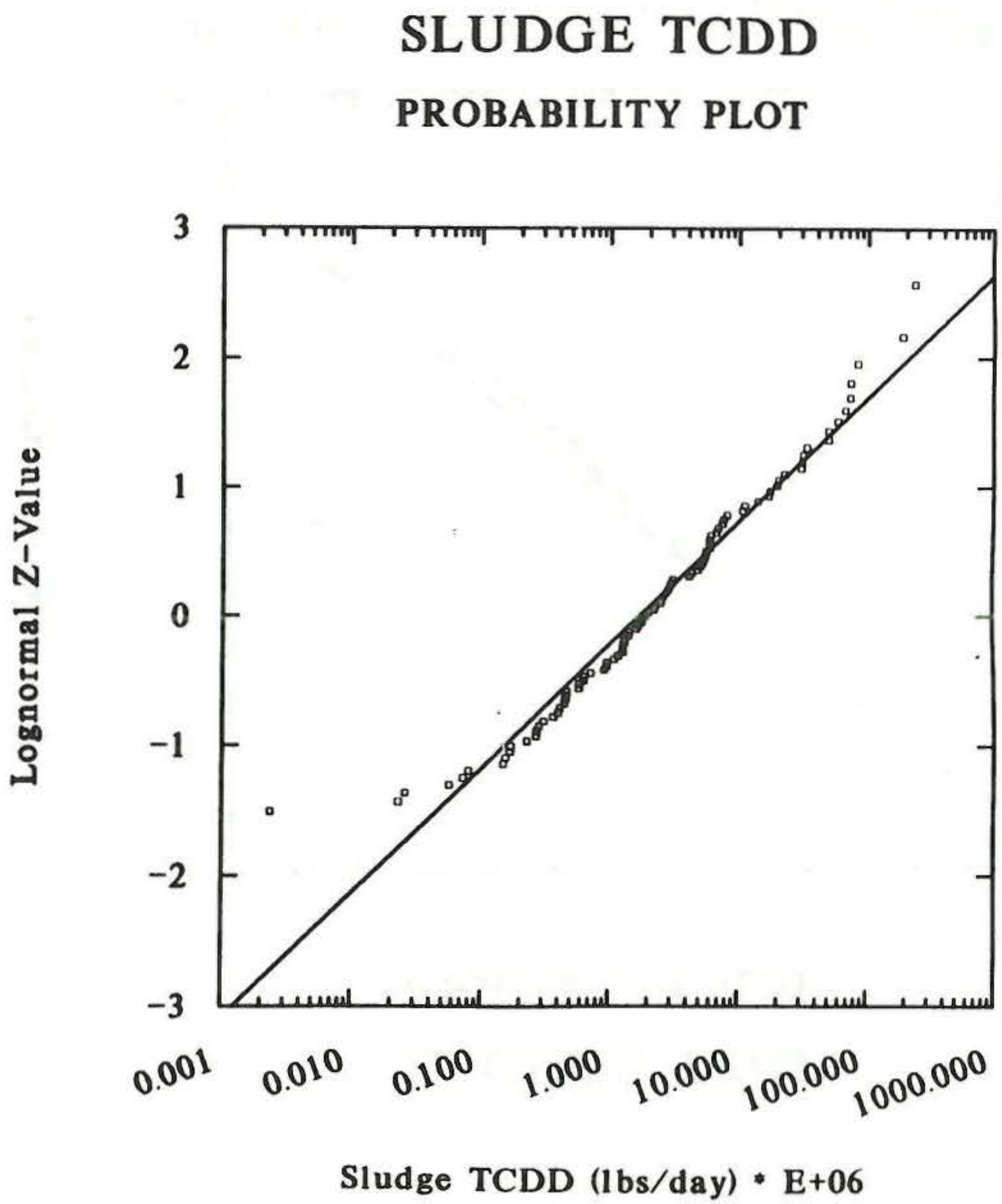

SLUDGE TCDD
PROBABILITY PLOT
Lognormal Z-Value
3
2
1
0
-1
-2
-3
0.001
0.010
0.100
1.000
10.000
100.000
1000.000
Sludge TCDD (lbs/day) * E+06

FIGURE B-10

SLUDGE TCDF

PROBABILITY PLOT

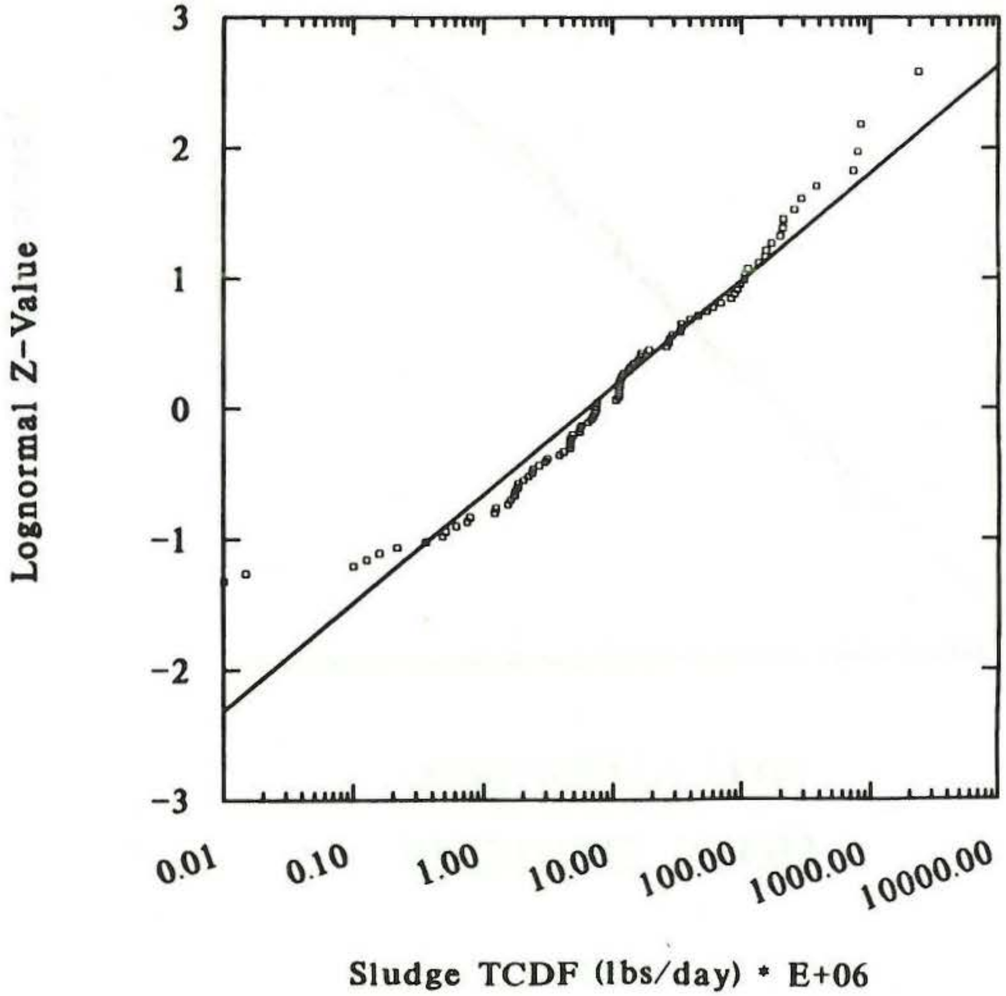


FIGURE B-11

EFFLUENT TCDD

PROBABILITY PLOT

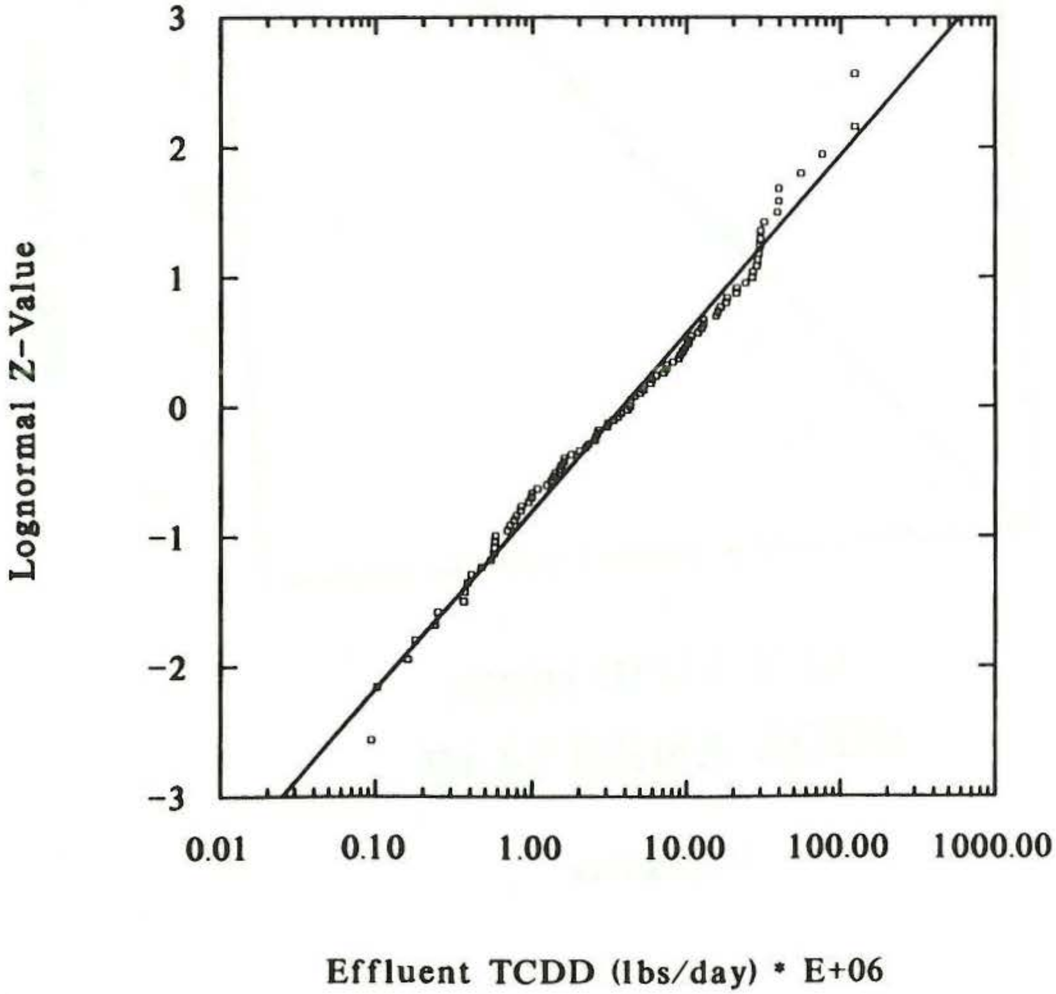


FIGURE B-12

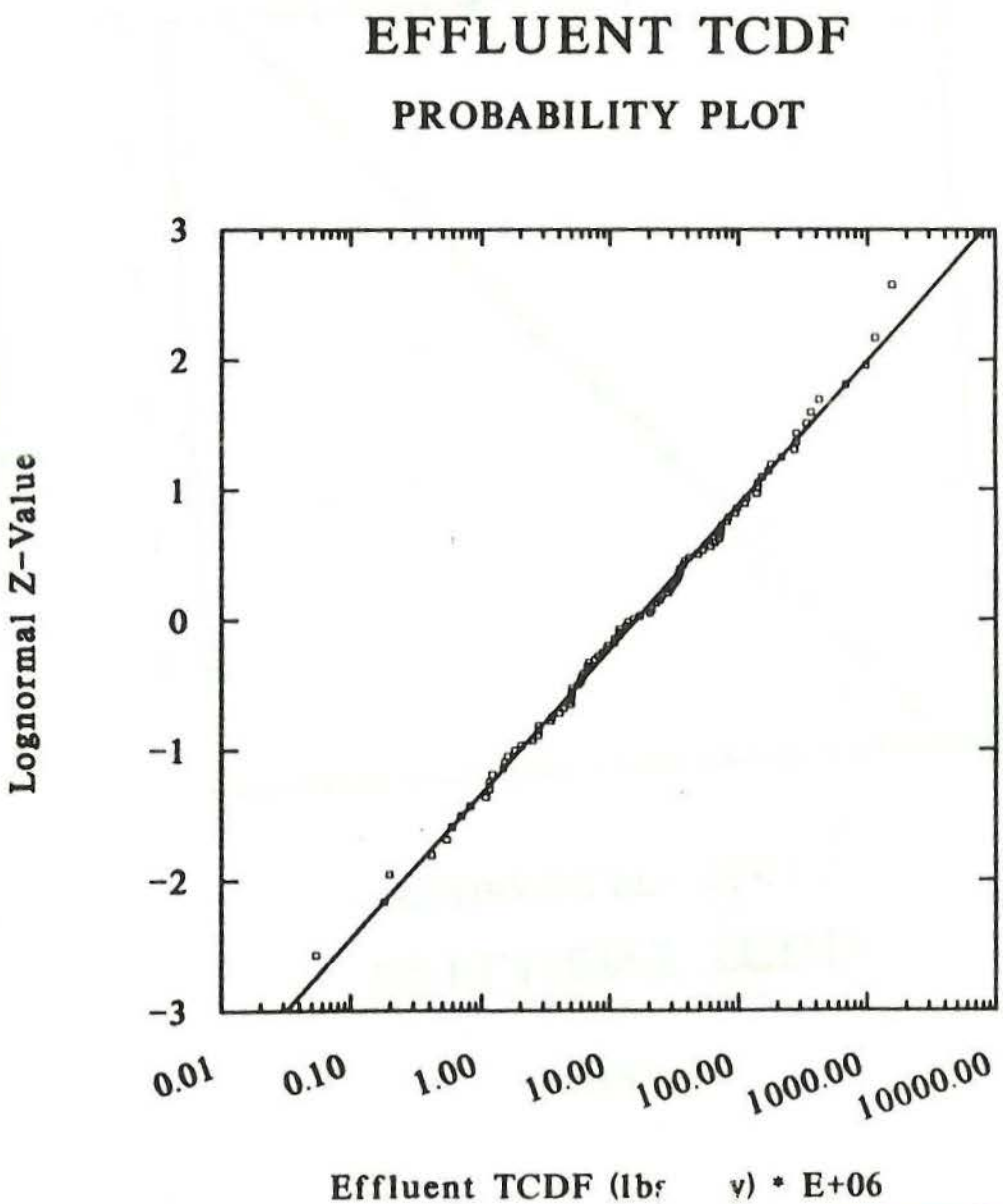

EFFLUENT TCDF
PROBABILITY PLOT
3
2
1
0
−1
−2
−3
Lognormal Z-Value
0.01
0.10
1.00
10.00
100.00
1000.00
10000.00
Effluent TCDF (lb
y) * E+06

FIGURE B-13

ADJUSTED PULP TCDD

PROBABILITY PLOT

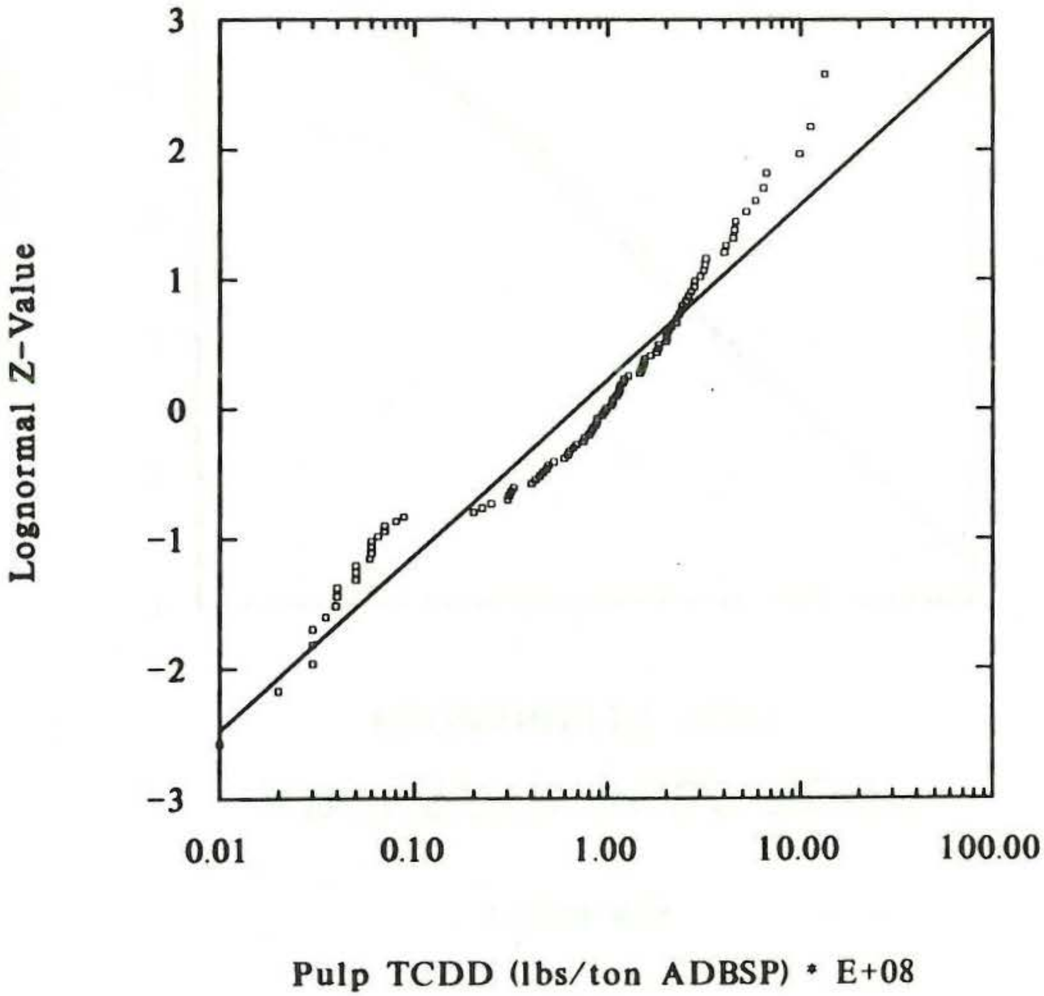


FIGURE B-14

ADJUSTED PULP TCDF

PROBABILITY PLOT

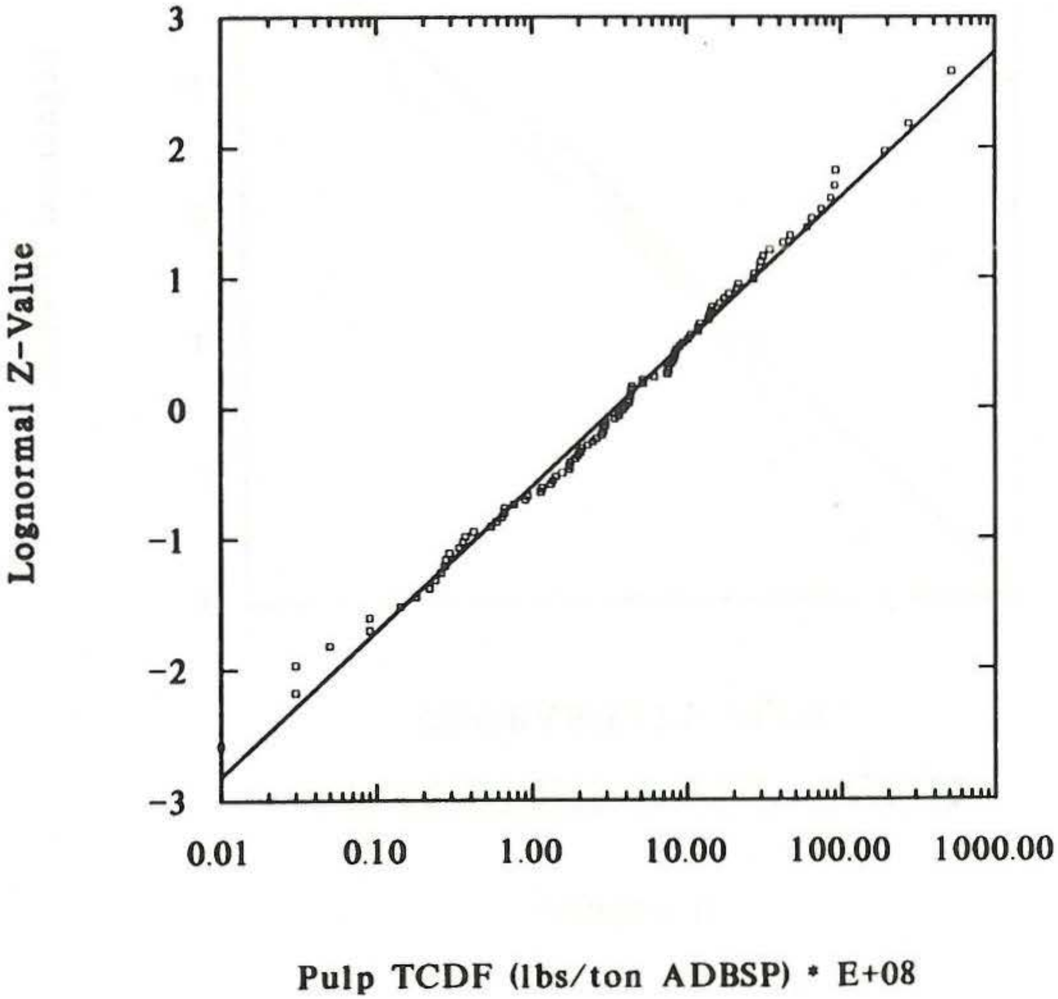


FIGURE B-15

ADJUSTED SLUDGE TCDD

PROBABILITY PLOT

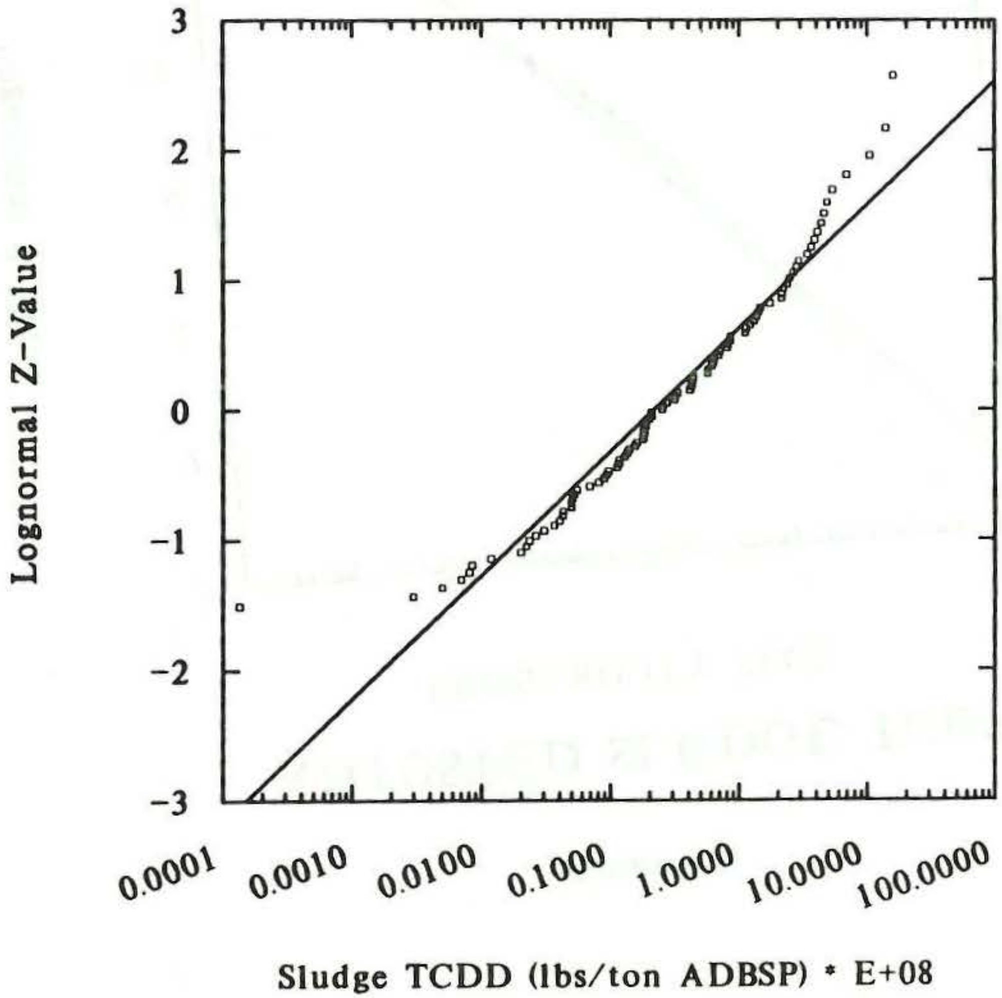


FIGURE B-16

ADJUSTED SLUDGE TCDF

PROBABILITY PLOT

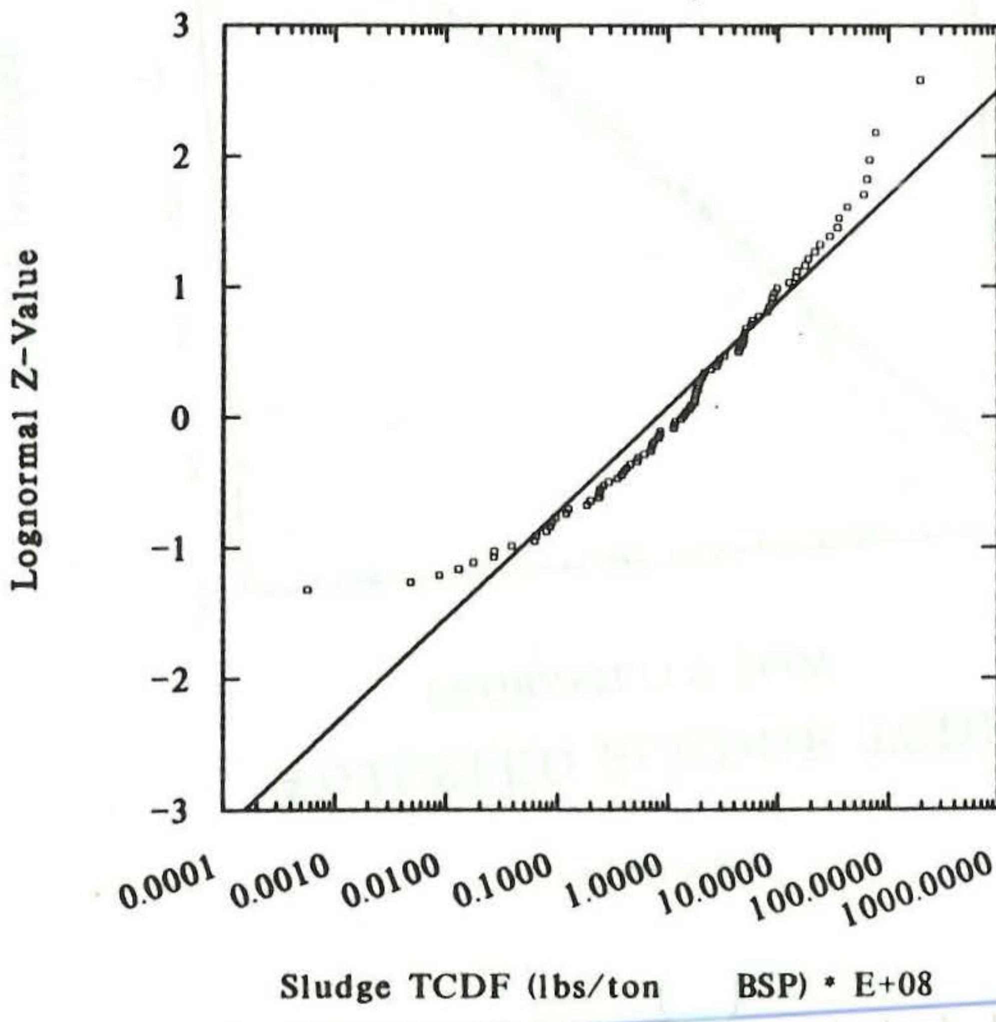


FIGURE B-17

ADJUSTED EFFLUENT TCDD

PROBABILITY PLOT

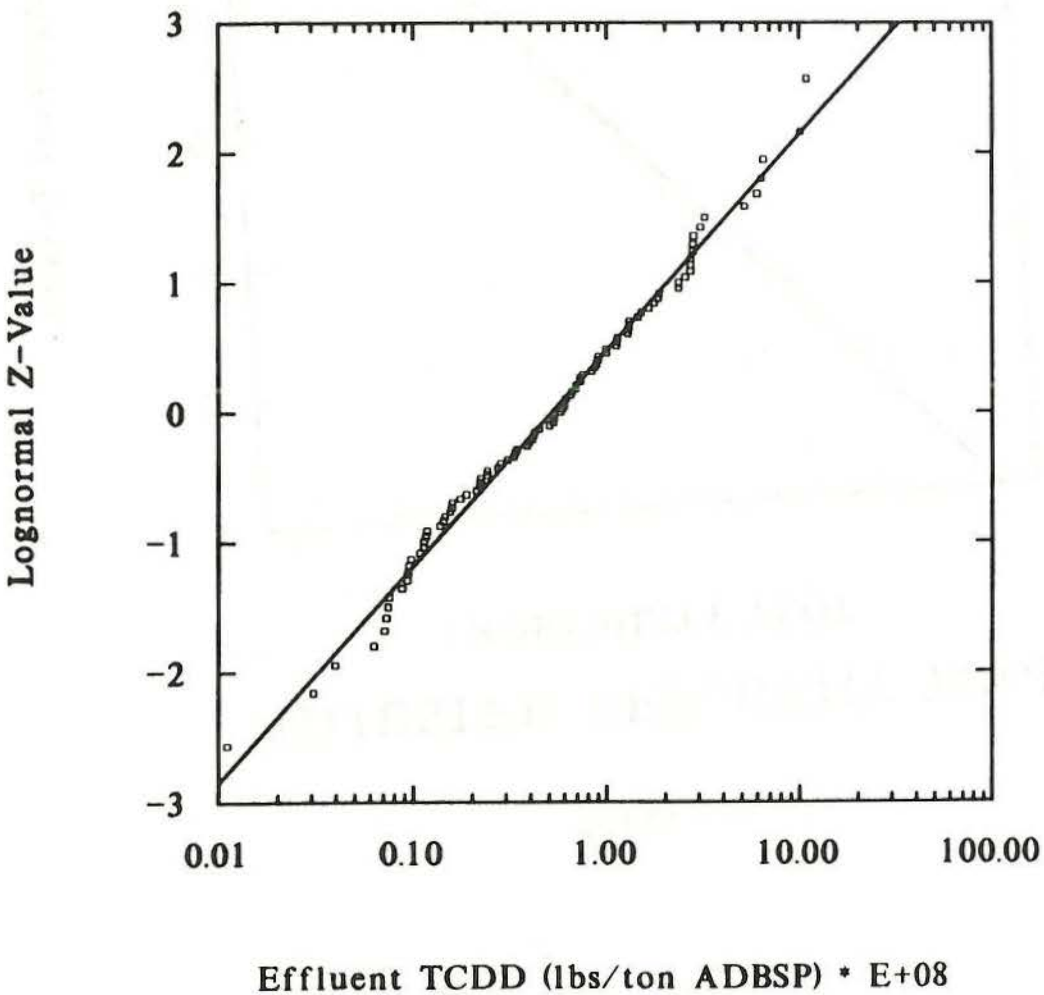


FIGURE B-18

ADJUSTED EFFLUENT TCDF

PROBABILITY PLOT

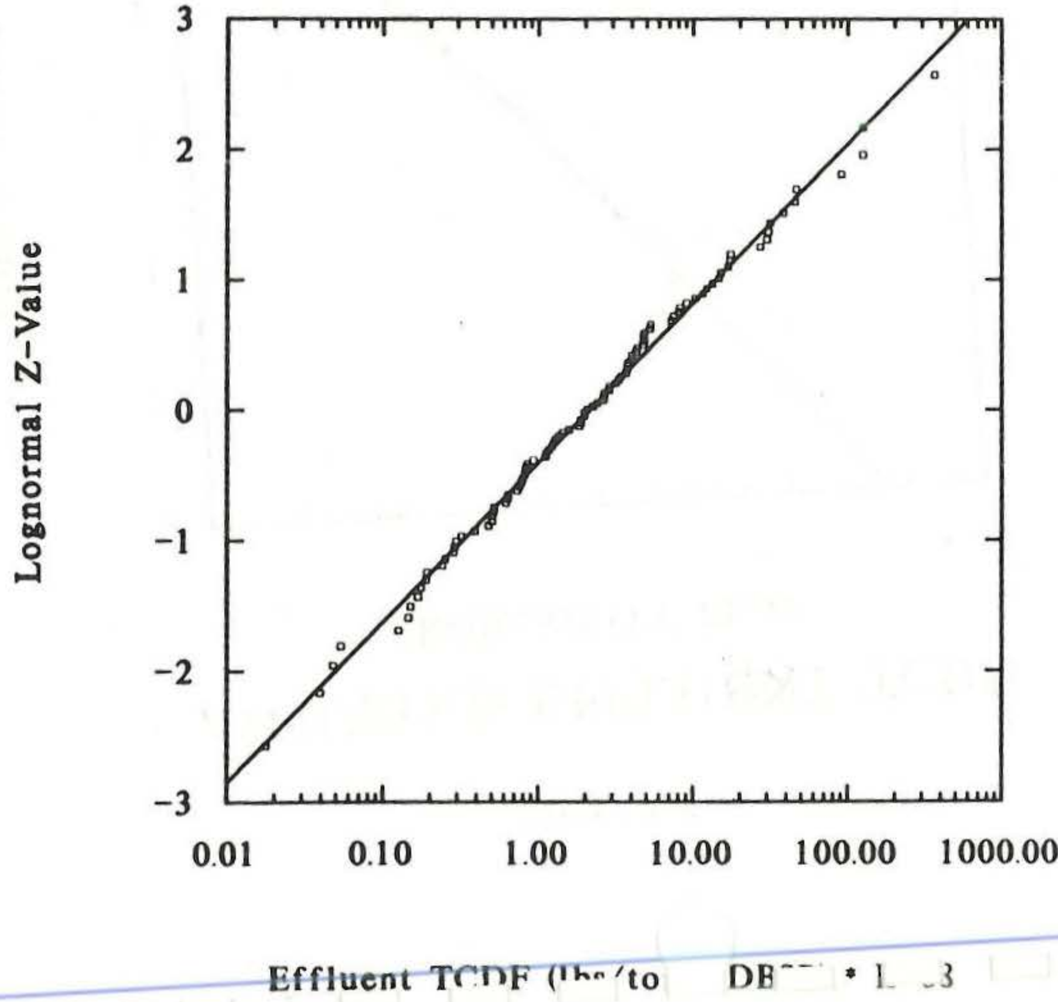
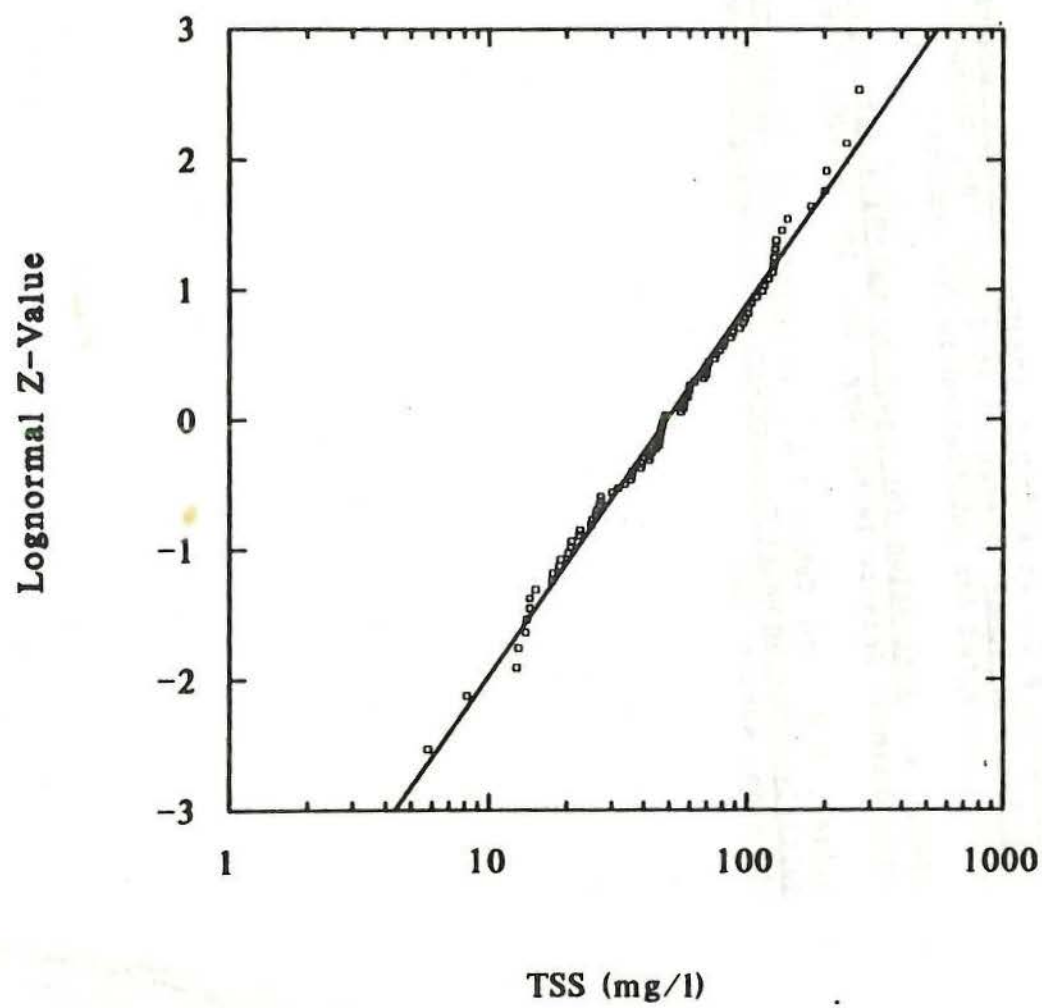


FIGURE B-19

TSS

PROBABILITY PLOT



REFERENCES

1. Amendola, G., et.al., The Occurrence and Fate of PCDDs and PCDFs in Five Bleached Kraft Pulp and Paper Mills, Chemosphere, Vol. 18, Nos. 1-6, pp 1181-1188, 1989.

2. U.S. EPA Cooperative Dioxin Screening Study, U.S. EPA, Office of Water Regulations and Standards, Washington, D.C., March, 1988, EPA-440/1-88-025.

3. U.S. EPA/Paper Industry Cooperative Dioxin Study, Washington, D.C., April 26, 1988. (104 Mill Study Agreement)

4. USEPA/Paper Industry Cooperative Dioxin Study: The 104 Mill Study, Technical Bulletin No. 590, National Council of the Paper Industry for Air and Stream Improvement, Inc., New York, New York, May 1990.

5. Whittemore, R.C., et.al., U.S. EPA/Paper Industry Cooperative Dioxin Study: The 104 Mill Study, presented at Dioxin '89, Toronto, Ontario, September 1989. (Accepted for publication in Chemosphere.)

6. Gleit, A., Estimation for Small Normal Data Sets with Detection Limits, Environmental Science Technology, Vol. 19, pp 1201-1206, 1985.

7. Helsel, D.R. and Cohn, T.A., Estimation of Descriptive Statistics for Multiply-Censored Water Quality Data, U.S. Geological Survey, Water Resources Division, August 1988.

U.S. EPA / PAPER INDUSTRY COOPERATIVE DIOXIN STUDY

ANALYTICAL RESULTS

This report presents all analytical data for 2,3,7,8-TCDD and 2,3,7,8-TCDF in pulp, effluent and sludge received to date under the Cooperative Dioxin Study. Data are listed by mill. Abbreviations used in this report are defined below. If there are any questions concerning the data, contact Jennie Helms at (202)382-7155.

UNITS: The unit of measurement for 2378-TCDD/TCDF concentration
- ppt = part per trillion
- ppq = part per quadrillion

2378-TCDD/TCDF CONCENTRATION: Reported value of chemical concentration
- ND = Not Detected, in these instances the value reported is the detection limit
- NQ = Not Quantified, lab analyses are being re-run for these samples

LAB: The analytical laboratory which completed the analysis
- CAL = California Analytical Laboratories Enseco, CA
- WSU = Brehm Laboratory, Wright State Univ. Dayton, OH
- TRI = Triangle Laboratories Research Triangle Park, NC

NOTES: Comments on analysis or sample origin
- LDUP = laboratory duplicate sample
- FDUP = field duplicate sample

SAMPLE DATE: Date on which the mill began collecting five-day composite samples of pulp, effluent and sludge. The sample date is a general indicator of the timeframe for sample collection.

OCT 27 1992

J-3

03/09/90

U.S. EPA/ Paper Industry
Cooperative Dioxin Study

Analytical Results

Sample Matrix	Units	2378-TCDD Concentration		2378-TCDF Concentration		Lab	Comments	Sample Date
** State: AK								
* Alaska Pulp Corp.				Sitka				
Effluent	ppq	7.7	ND	32.0		CAL		08/27/88
Pulp	ppt	0.7	ND	1.4		WSU		08/27/88
Sludge	ppt	4.7		42.0		CAL		08/27/88
* Ketchikan Pulp & Paper Co.				Ketchikan				
Effluent	ppq	6.7	ND	5.3	ND	CAL		08/15/88
Effluent	ppq	15.0		7.2		CAL		08/15/88
Pulp	ppt	0.3	ND	0.3	ND	WSU		08/15/88
Sludge	ppt	3.5		0.0	NQ	CAL	LDUP	08/15/88
Sludge	ppt	0.4		2.0			LDUP	08/15/88

03/09/90

U.S. EPA/ Paper Industry
Cooperative Dioxin Study

Analytical Results

Sample Matrix	Units	2378-TCDD Concentration		2378-TCDF Concentration		Lab	Comments	Sample Date
** State: AL								
* Alabama River Pulp				Claiborne				
Effluent	ppq	41.0		250.0		CAL	FDUP	06/07/88
Effluent	ppq	40.0		250.0		CAL	FDUP	06/07/88
Effluent	ppq	46.0		210.0		CAL	FDUP	06/07/88
Pulp	ppt	43.0		120.0		WSU		06/07/88
Pulp	ppt	3.9		97.0		WSU	FDUP	06/07/88
Pulp	ppt	3.8		98.0		WSU	FDUP	06/07/88
Sludge	ppt	81.0		373.0		CAL	FDUP	06/07/88
Sludge	ppt	73.0		393.0		CAL	FDUP	06/07/88
Sludge	ppt	68.0		342.0		CAL	FDUP	06/07/88
* Boise Cascade Corp.				Jackson				
Effluent	ppq	120.0		630.0		CAL	FDUP	06/17/88
Effluent	ppq	95.0		540.0		CAL	FDUP	06/17/88
Pulp	ppt	11.0		104.0		WSU	FDUP	06/17/88
Pulp	ppt	9.1		71.0		WSU	FDUP	06/17/88
Sludge	ppt	18.0		147.0		CAL	FDUP	06/17/88
Sludge	ppt	18.0		169.0		CAL	FDUP	06/17/88
* Champion International				Courtland				
Effluent	ppq	77.0		340.0		CAL		06/24/88
Pulp	ppt	3.5		7.6		WSU		06/24/88
Pulp	ppt	23.0		102.0		WSU		06/24/88
Sludge	ppt	215.0		923.0		CAL		06/24/88
* Container Corp. of America				Brewton				
Effluent	ppq	6.5		10.0	ND	CAL		07/01/88
Pulp	ppt	2.3		4.5		WSU		07/01/88
Sludge	ppt	16.0		34.0		CAL		07/01/88
* Gulf States Paper Corp.				Demopolis				
Effluent	ppq	38.0		110.0		CAL		06/14/88
Pulp	ppt	5.2		20.0		WSU		06/14/88
Sludge	ppt	51.0		0.0	NQ	CAL	LDUP	06/14/88
Sludge	ppt	37.0		107.0		CAL	LDUP	06/14/88
* International Paper Co.				Mobile				
Effluent	ppq	0.0	NQ	850.0		CAL	LDUP	10/24/88
Effluent	ppq	100.0		490.0		CAL	LDUP	10/24/88
Pulp	ppt	20.0		104.0		WSU		10/24/88
Pulp	ppt	21.0		106.0		WSU		10/24/88
Pulp	ppt	3.5		14.0		WSU		10/24/88
Pulp	ppt	27.0		138.0		CAL		10/24/88
Sludge	ppt	108.0		617.0		CAL		10/24/88

03/09/90

U.S. EPA/ Paper Industry
Cooperative Dioxin Study

Analytical Results

Sample Matrix	Units	2378-TCDD Concentration		2378-TCDF Concentration	Lab	Comments	Sample Date
* International Paper Co.				Selma			
Effluent	ppq	81.0		310.0	CAL		06/26/88
Pulp	ppt	2.1		21.0	WSU		06/26/88
Pulp	ppt	4.7		22.0	WSU		06/26/88
Sludge	ppq	680.0		2900.0	CAL	Non-dewatered	06/26/88
* James River Corp.				Butler			
Effluent	ppq	23.0		72.0	CAL		06/16/88
Pulp	ppt	3.3		19.0	WSU		06/16/88
Pulp	ppt	1.2		1.4	WSU		06/16/88
Pulp	ppt	3.7		30.0	WSU		06/16/88
Sludge	ppq	330.0		1100.0	CAL	Non-dewatered	06/16/88
* Kimberly-Clark Corp.				Coosa Pines			
Effluent	ppq	35.0		74.0	CAL		08/26/88
Pulp	ppt	0.3	ND	1.0	WSU		08/26/88
Pulp	ppt	4.1		7.3	WSU		08/26/88
Pulp	ppt	11.0		38.0	WSU		08/26/88
Pulp	ppt	2.6		3.3	WSU		08/26/88
Sludge	ppq	3800.0		9200.0	CAL	Non-dewatered	08/26/88
* Scott Paper Co.				Mobile			
Effluent	ppq	14.0		19.0	CAL		01/13/89
Pulp	ppt	1.7		2.2	CAL		01/13/89
Pulp	ppt	0.6		0.8	CAL		01/13/89
Pulp	ppt	2.2		4.3	CAL		10/24/88
Sludge	ppt	9.5		18.0	CAL		01/13/89

03/09/90

U.S. EPA/ Paper Industry
Cooperative Dioxin Study

Analytical Results

Sample Matrix	Units	2378-TCDD Concentration		2378-TCDF Concentration	Lab	Comments	Sample Date
** State: AR							
* Georgia-Pacific Corp.				Crosset			
Effluent	ppq	96.0		370.0	CAL		09/02/88
Pulp	ppt	6.0		59.0	WSU		09/02/88
Pulp	ppt	7.7		89.0	WSU		09/02/88
Pulp	ppt	19.0		308.0	WSU		09/02/88
Sludge	ppt	168.0		1680.0	CAL	PRIM	09/02/88
Sludge	ppq	0.0	NQ	740.0	CAL	LDUP Non-dewa tered	09/02/88
Sludge	ppq	190.0		710.0	CAL	LDUP Non-dewa tered	09/02/88
* International Paper Co.				Pine Bluff			
Effluent	ppq	110.0		1100.0	CAL		06/17/88
Pulp	ppt	21.0		647.0	WSU	LDUP	06/17/88
Pulp	ppt	23.0		661.0	WSU	LDUP	06/17/88
Pulp	ppt	5.0		57.0	WSU		06/17/88
Sludge	ppt	185.0		2940.0	CAL		06/17/88
* Nekoosa Papers, Inc.				Ashdown			
Effluent	ppq	41.0		94.0	CAL		10/08/88
Pulp	ppt	2.8		27.0	WSU		10/08/88
Pulp	ppt	5.5		12.0	WSU		10/08/88
Sludge	ppt	13.0		30.0	CAL		10/08/88
* Potlatch Corp.				McGhee			
Effluent	ppq	40.0		100.0	CAL		07/15/88
Pulp	ppt	21.0		59.0	WSU		07/15/88
Pulp	ppt	12.0		83.0	WSU		07/15/88
Sludge	ppt	91.0		433.0	CAL		07/15/88

U.S. EPA/ Paper Industry Cooperative Dioxin Study

Analytical Results

Sample Matrix	Units	2378-TCDD Concentration		2378-TCDF Concentration	Lab	Comments	Sample Date
** State: AZ							
* Stone Container Corp.				Snowflake			
Effluent	ppq	5.5		39.0	CAL		07/17/88
Pulp	ppt	0.7	ND	1.3	WSU		07/17/88

U.S. EPA/ Paper Industry Cooperative Dioxin Study

Analytical Results

Sample Matrix	Units	2378-TCDD Concentration		2378-TCDF Concentration	Lab	Comments	Sample Date
** State: CA							
* Gaylord Container Corp.				Antioch			
Effluent	ppq	49.0		800.0	CAL		10/15/88
Pulp	ppt	32.0		969.0	WSU		10/15/88
Sludge	ppt	101.0		1570.0	CAL		10/15/88
* Louisiana Pacific Corp.				Samoa			
Effluent	ppq	0.0	NQ	320.0	CAL	LDUP	11/20/88
Effluent	ppq	67.0		170.0	CAL	LDUP	11/20/88
Pulp	ppt	9.1		59.0	CAL		11/20/88
* Simpson Paper Co.				Anderson			
Effluent	ppq	250.0		8400.0	CAL		06/24/88
Pulp	ppt	49.0		2620.0	WSU		06/24/88
Sludge	ppt	278.0		6740.0	CAL		06/24/88
* Simpson Paper Co.				Fairhaven			
Effluent	ppq	100.0		660.0	CAL		08/06/88
Pulp	ppt	20.0		106.0	CAL		08/06/88

03/09/90

U.S. EPA/ Paper Industry
Cooperative Dioxin Study

Analytical Results

Sample Matrix	Units	2378-TCDD Concentration		2378-TCDF Concentration		Lab	Comments	Sample Date
** State: FL								
* Buckeye Cellulose				Perry				
Effluent	ppq	27.0		80.0		CAL		06/14/88
Pulp	ppt	0.5		0.7		CAL		06/14/88
Pulp	ppt	0.8	ND	2.5		CAL		06/14/88
Sludge	ppt	12.0		40.0		CAL	PRIM	06/14/88
* Champion International				Cantonment				
Effluent	ppq	11.0	ND	38.0		CAL		01/15/88
Pulp	ppt	0.7	ND	4.1		WSU	LDUP	01/15/88
Pulp	ppt	1.0	ND	0.7	ND	CAL	LDUP	01/15/88
Pulp	ppt	2.0		2.2		WSU	FDUP LDUP	01/15/88
Pulp	ppt	2.0		0.9		CAL	LDUP,FDU P	01/15/88
Pulp	ppt	4.9		1.1		CAL	FDUP	01/15/88
Sludge	ppt	14.0		21.0		CAL		01/15/88
* Georgia-Pacific Corp.				Palatka				
Effluent	ppq	16.0		38.0		CAL		07/05/88
Pulp	ppt	0.5	ND	0.9	ND	WSU		07/05/88
Pulp	ppt	0.5	ND	2.4		WSU		07/05/88
Sludge	ppq	92.0		410.0		CAL	Non-dewa tered	07/05/88
* ITT-Rayonier, Inc.				Fernandina Beach				
Effluent	ppq	7.0		35.0		CAL		07/06/88
Pulp	ppt	0.2	ND	0.5	ND	WSU		07/07/88
Sludge	ppt	4.7		32.0		CAL		07/06/88
* St. Joe Paper Co.				Port St. Joe				
Effluent	ppq	21.0		60.0		CAL		08/02/88
Pulp	ppt	2.2		5.7		WSU		08/02/88
* Stone Container Corp.				Panama City				
Effluent	ppq	8.4	ND	7.9		CAL		07/19/88
Effluent	ppq	6.9		18.0		CAL	POTW Effluent	07/19/88
Pulp	ppt	0.1	ND	6.6		WSU		07/19/88
Sludge	ppt	3.6		16.0		CAL		07/19/88

U.S. EPA/ Paper Industry
Cooperative Dioxin Study

Analytical Results

Sample Matrix	Units	2378-TCDD Concentration		2378-TCDF Concentration		Lab	Comments	Sample Date
** State: GA								
* Brunswick Pulp and Paper				Brunswick				
Effluent	ppq	30.0		68.0		CAL	FDUP	08/26/88
Effluent	ppq	30.0		50.0		CAL	FDUP	08/26/88
Pulp	ppt	6.3		8.0		WSU	FDUP	08/26/88
Pulp	ppt	6.1		9.4		WSU	FDUP	08/26/88
Pulp	ppt	1.9		3.5		WSU	FDUP	08/26/88
Pulp	ppt	1.6		2.9		WSU	FDUP	08/26/88
Pulp	ppt	3.6		4.3		WSU		08/26/88
Pulp	ppt	8.3		12.0		WSU		08/26/88
Sludge	ppt	33.0		62.0		CAL		08/26/88
* Buckeye Cellulose				Oglethorpe				
Effluent	ppq	12.0	ND	26.0		CAL		07/23/88
Pulp	ppt	0.5	ND	0.9	ND	CAL		07/23/88
Sludge	ppt	2.6		6.1		CAL	LDUP	07/23/88
Sludge	ppt	2.6		3.0		CAL	LDUP	07/23/88
* Federal Paper Board Co.				Augusta				
Effluent	ppq	16.0		47.0		CAL		06/10/88
Pulp	ppt	2.4		7.9		WSU		06/10/88
Pulp	ppt	4.9		15.0		WSU		06/10/88
Pulp	ppt	7.9		19.0		WSU		06/10/88
Sludge	ppq	680.0		1400.0		CAL	Non-dewa tered	06/10/88
* Gilman Paper Co.				St. Marys				
Effluent	ppq	6.5	ND	17.0		CAL		09/02/88
Pulp	ppt	2.8		6.8		WSU		09/02/88
Pulp	ppt	3.7		12.0		WSU		09/02/88
Sludge	ppq	220.0		610.0		CAL	Non-dewa tered	09/02/88
* ITT-Rayonier, Inc.				Jesup				
Effluent	ppq	24.0		0.0	NQ	CAL	LDUP	07/24/88
Effluent	ppq	23.0		16.0		CAL		07/24/88
Effluent	ppq	11.0		4.2		CAL	LDUP	07/24/88
Pulp	ppt	0.6	ND	0.8	ND	CAL		07/24/88
Pulp	ppt	0.3	ND	0.8		WSU		07/24/88
Pulp	ppt	0.7	ND	0.6		WSU		07/24/88
Pulp	ppt	0.7	ND	0.9		WSU		07/24/88
Sludge	ppt	3.0		2.4		CAL		07/24/88

U.S. EPA/ Paper Industry
Cooperative Dioxin Study

Analytical Results

Sample Matrix	Units	2378-TCDD Concentration	2378-TCDF Concentration	Lab	Comments	Sample Date
** State: ID						
* Potlatch Corp.			Lewiston			
Effluent	ppq	71.0	360.0	CAL	FDUP	07/26/88
Effluent	ppq	79.0	320.0	CAL	FDUP	07/26/88
Pulp	ppt	25.0	153.0	WSU	FDUP	07/26/88
Pulp	ppt	27.0	147.0	WSU	FDUP	07/26/88
Sludge	ppt	78.0	639.0	CAL		07/26/88

U.S. EPA/ Paper Industry
Cooperative Dioxin Study

Analytical Results

Sample Matrix	Units	2378-TCDD Concentration		2378-TCDF Concentration		Lab	Comments	Sample Date
** State: KY								
* Westvaco Corp.				Wickliffe				
Effluent	ppq	35.0		150.0		CAL		07/23/88
Pulp	ppt	12.0		55.0		WSU	LDUP	07/23/88
Pulp	ppt	11.0		54.0		WSU	LDUP	07/23/88
Pulp	ppt	2.1		25.0		WSU		07/23/88
Sludge	ppt	9.4		46.0		CAL		07/23/88
* Wilamette Industries				Hawesville				
Effluent	ppq	11.0	ND	8.0	ND	CAL		10/28/88
Pulp	ppt	0.3	ND	1.1		WSU		10/28/88
Pulp	ppt	0.5	ND	1.9		WSU		10/28/88
Sludge	ppq	83.0		380.0		CAL	Non-dewatered	10/28/88
Sludge	ppq	52.0		210.0		CAL	Non-dewatered	10/28/88

U.S. EPA/ Paper Industry
Cooperative Dioxin Study

Analytical Results

Sample Matrix	Units	2378-TCDD Concentration	2378-TCDF Concentration	Lab	Comments	Sample Date
** State: LA						
* Boise Cascade Corp.			Deridder			
Effluent	ppq	9.2	44.0	CAL		06/10/88
Pulp	ppt	5.3	8.7	WSU		06/10/88
Sludge	ppq	280.0	440.0	CAL	Non-dewa tered	06/10/88
* Georgia-Pacific Corp.			Zachary			
Effluent	ppq	190.0	0.0 NQ	CAL	LDUP	07/21/88
Effluent	ppq	160.0	3000.0	CAL	LDUP	07/21/88
Pulp	ppt	16.0	539.0	WSU		07/21/88
Pulp	ppt	5.2	78.0	WSU		07/21/88
Pulp	ppt	27.0	632.0	WSU		07/21/88
Sludge	ppt	17.0	421.0	CAL		07/21/88
* International Paper Co.			Bastrop			
Effluent	ppq	330.0	1600.0	CAL		06/20/88
Pulp	ppt	5.1	22.0	WSU	FDUP	06/20/88
Pulp	ppt	5.7	23.0	WSU	FDUP	06/20/88
Pulp	ppt	6.3	42.0	WSU		06/20/88
Sludge	ppt	140.0	677.0	CAL		06/20/88
* James River Corp.			St. Francesville			
Effluent	ppq	82.0	320.0	CAL		06/20/88
Pulp	ppt	6.4	19.0	WSU		06/20/88
Pulp	ppt	4.9	15.0	WSU		06/20/88
Sludge	ppt	96.0	243.0	CAL		06/20/88

U.S. EPA/ Paper Industry
Cooperative Dioxin Study

Analytical Results

Sample Matrix	Units	2378-TCDD Concentration	2378-TCDF Concentration	Lab	Comments	Sample Date
** State: MD						
* Westvaco Corp.			Luke			
Effluent	ppq	16.0	49.0	CAL		06/28/88
Pulp	ppt	29.0	157.0	WSU		06/28/88
Sludge	ppt	80.0	471.0	CAL		06/28/88

03/09/90

U.S. EPA/ Paper Industry
Cooperative Dioxin Study

Analytical Results

Sample Matrix	Units	2378-TCDD Concentration		2378-TCDF Concentration	Lab	Comments	Sample Date
** State: ME							
* Boise Cascade Corp.				Rumford			
Effluent	ppq	120.0		570.0	CAL		06/02/88
Pulp	ppt	116.0		800.0	WSU		06/02/88
Pulp	ppt	17.0		111.0	WSU		06/02/88
Sludge	ppt	105.0		674.0	CAL		06/02/88
* Georgia-Pacific Corp.				Woodland			
Effluent	ppq	6.8		25.0	CAL		07/22/88
Pulp	ppt	0.4	ND	0.9	WSU		07/22/88
Sludge	ppt	1.9	ND	7.3	CAL		07/22/88
* International Paper Co.				Jay			
Effluent	ppq	88.0		420.0	WSU		01/15/87
Pulp	ppt	26.0		140.0	WSU		01/15/87
Pulp	ppt	51.0		180.0	WSU		01/15/87
Sludge	ppt	500.0		2100.0	WSU	SEC	01/15/87
Sludge	ppt	180.0		760.0	WSU	COMB	01/15/87
* James River Corp.				Old Town			
Effluent	ppq	39.0		130.0	CAL		08/01/88
Pulp	ppt	13.0		51.0	WSU		08/01/88
Sludge	ppt	12.0		34.0	CAL		08/01/88
* Lincoln Pulp and Paper				Lincoln			
Effluent	ppq	32.0		130.0	CAL		11/19/88
Pulp	ppt	16.0		94.0	WSU		11/19/88
Sludge	ppt	48.0		223.0	CAL		11/19/88
* Scott Paper Co.				Hinckley			
Effluent	ppq	19.0		100.0	CAL	FDUP	06/28/88
Effluent	ppq	16.0		63.0	CAL	FDUP	06/28/88
Pulp	ppt	1.9		10.0	WSU		06/28/88
Pulp	ppt	8.5		37.0	WSU	FDUP	06/28/88
Pulp	ppt	7.9		35.0	WSU	FDUP	06/28/88
Sludge	ppt	33.0		106.0	CAL	FDUP	06/28/88
Sludge	ppt	6.9		29.0	CAL		06/28/88
Sludge	ppt	39.0		149.0	CAL	FDUP	06/28/88
Sludge	ppt	67.0		330.0	CAL		06/28/88
* Scott Paper Co.				Westbrook			
Effluent	ppq	6.3		12.0	CAL		06/30/88
Pulp	ppt	4.2		16.0	WSU		06/30/88
Pulp	ppt	8.1		30.0	WSU		06/30/88
Sludge	ppt	13.0		55.0	CAL		06/30/88

U.S. EPA/ Paper Industry
Cooperative Dioxin Study

Analytical Results

Sample Matrix	Units	2378-TCDD Concentration		2378-TCDF Concentration	Lab	Comments	Sample Date
** State: MI							
* Champion International				Quinnesec			
Effluent	ppq	9.0		66.0	WSU		12/15/87
Pulp	ppt	7.7		50.0	CAL	FDUP	12/15/87
Pulp	ppt	7.8		45.0	CAL	FDUP	12/15/87
Sludge	ppt	95.0		735.0	WSU		12/15/87
* Mead Corporation				Escanaba			
Effluent	ppq	17.0	ND	50.8	WSU		12/15/87
Pulp	ppt	25.0		116.0	CAL		12/15/87
Pulp	ppt	18.0		68.0	CAL	FDUP	12/15/87
Pulp	ppt	15.0		39.0	CAL	FDUP	12/15/87
Sludge	ppt	125.0		574.0	WSU		12/15/87
* Scott Paper Co.				Muskegon			
Effluent	ppq	8.4	ND	42.0	CAL		06/13/88
Pulp	ppt	0.3	ND	1.0	WSU	LDUP	06/13/88
Pulp	ppt	0.4	ND	1.4	WSU	LDUP	06/13/88

03/09/90

U.S. EPA/ Paper Industry
Cooperative Dioxin Study

Analytical Results

Sample Matrix	Units	2378-TCDD Concentration	2378-TCDF Concentration	Lab	Comments	Sample Date
** State: MN						
* Boise Cascade Corp.			International Falls			
Effluent	ppq	120.0	2200.0	WSU		06/25/86
Pulp	ppt	4.9	47.0	WSU		06/25/86
Pulp	ppt	3.0	50.0	WSU		06/25/86
Pulp	ppt	16.0	330.0	WSU		06/25/86
Sludge	ppt	710.0	10900.0	WSU	SEC	06/25/86
Sludge	ppt	37.0	680.0	WSU	COMB	06/25/86
Sludge	ppt	24.0	380.0	WSU	PRIM	06/25/86
* Potlatch Corp.			Cloquet			
Effluent	ppq	24.0	46.0	CAL		09/24/88
Pulp	ppt	1.2	5.0	CAL		09/24/88
Pulp	ppt	2.4	7.9	CAL		09/24/88
Sludge	ppt	5.0	25.0	CAL		09/24/88

03/09/90

U.S. EPA/ Paper Industry
Cooperative Dioxin Study

Analytical Results

Sample Matrix	Units	2378-TCDD Concentration	2378-TCDF Concentration		Lab	Comments	Sample Date
** State: MS							
* International Paper Co.			Moss Point				
Effluent	ppq	160.0	920.0		CAL		06/07/88
Pulp	ppt	7.3	36.0		WSU		06/07/88
Pulp	ppt	15.0	105.0		WSU		06/07/88
Sludge	ppt	161.0	1020.0		CAL		06/07/88
* International Paper Co.			Natchez				
Effluent	ppq	38.0	220.0		CAL		08/12/88
Pulp	ppt	3.6	15.0		CAL		08/12/88
Pulp	ppt	2.2	3.0		CAL		08/12/88
Sludge	ppt	14.0	78.0		CAL	PRIM	08/12/88
* Leaf River Forest Products			New Augusta				
Effluent	ppq	200.0	410.0		CAL		02/27/88
Pulp	ppt	15.0	35.0		CAL	FDUP	12/02/88
Pulp	ppt	14.0	23.0		CAL	FDUP	12/02/88
Pulp	ppt	3.8	7.7		CAL		02/27/88
Sludge	ppt	681.0	0.0	NQ	CAL		02/27/88

U.S. EPA/ Paper Industry
Cooperative Dioxin Study

Analytical Results

Sample Matrix	Units	2378-TCDD Concentration	2378-TCDF Concentration		Lab	Comments	Sample Date
** State: NC							
* Champion International			Canton				
Effluent	ppq	15.0	7.2		CAL		04/21/88
Pulp	ppt	17.0	27.0		WSU		04/21/88
Pulp	ppt	6.0	9.9		WSU		04/21/88
Pulp	ppt	6.5	11.0		WSU	FDUP	04/21/88
Pulp	ppt	4.6	5.5		WSU	FDUP	04/21/88
Pulp	ppt	5.8	10.0		WSU		04/21/88
Sludge	ppt	175.0	0.0	NQ	WSU	FDUP	04/21/88
Sludge	ppt	172.0	260.0		WSU	FDUP	04/21/88
* Federal Paper Board Co.			Riegelwood				
Effluent	ppq	28.0	61.0		CAL		12/13/88
Pulp	ppt	4.0	3.2		WSU		12/13/88
Pulp	ppt	4.3	4.7		WSU		12/13/88
Pulp	ppt	3.2	1.3		WSU	LDUP	12/13/88
Pulp	ppt	3.3	1.5		WSU	LDUP	12/13/88
Sludge	ppt	3.8	5.2		CAL	FDUP	12/13/88
Sludge	ppt	2.9	3.3		CAL	FDUP	12/13/88
* Weyerhauser Co.			New Bern				
Effluent	ppq	44.0	180.0		CAL		08/13/88
Pulp	ppt	7.5	45.0		WSU		08/13/88
Sludge	ppt	373.0	1920.0		CAL	FDUP	08/13/88
Sludge	ppt	213.0	1600.0		CAL	FDUP	08/13/88
* Weyerhauser Co.			Plymouth				
Effluent	ppq	320.0	4000.0		CAL		02/13/89
Pulp	ppt	10.0	82.0		CAL		02/13/89
Pulp	ppt	14.0	222.0		CAL		02/13/89
Pulp	ppt	33.0	318.0		CAL		02/13/89
Sludge	ppt	1390.0	17100.0		CAL		02/13/89

U.S. EPA/ Paper Industry
Cooperative Dioxin Study

Analytical Results

Sample Matrix	Units	2378-TCDD Concentration	2378-TCDF Concentration		Lab	Comments	Sample Date

** State: MT

* Stone Container Corp.			Missoula				
Effluent	ppq	3.1	7.6	ND	CAL		07/12/88
Pulp	ppt	4.1	13.0		WSU		07/12/88
Sludge	ppq	55.0	150.0		CAL	Non-dewatered	07/12/88

03/09/90

U.S. EPA/ Paper Industry
Cooperative Dioxin Study

Analytical Results

Sample Matrix	Units	2378-TCDD Concentration	2378-TCDF Concentration	Lab	Comments	Sample Date
** State: NH						
* James River Corp.			Berlin			
Effluent	ppq	59.0	1200.0	CAL		08/19/88
Effluent	ppq	17.0	61.0	CAL		05/08/89
Pulp	ppt	32.0	1110.0	WSU		08/19/88
Pulp	ppt	3.3	41.0	WSU		08/19/88
Pulp	ppt	3.8	39.0	CAL		05/08/89
Pulp	ppt	1.0	15.0	CAL		05/08/89
Sludge	ppt	104.0	2930.0	CAL	LDUP	08/19/88
Sludge	ppt	98.0	2170.0	CAL	LDUP	08/19/88
Sludge	ppt	18.0	195.0	CAL		05/08/89

03/09/90

U.S. EPA/ Paper Industry
Cooperative Dioxin Study

Analytical Results

Sample Matrix	Units	2378-TCDD Concentration		2378-TCDF Concentration		Lab	Comments	Sample Date
** State: NY								
* Finch, Pruyn & Co., Inc.				Glens Falls				
Effluent	ppq	7.9	ND	2.9	ND	CAL		01/13/89
Pulp	ppt	0.3	ND	0.3	ND	WSU		01/13/89
Sludge	ppt	3.7		0.0	NQ	CAL	LDUP	01/13/89
Sludge	ppt	1.2		7.4			LDUP	01/13/89
* International Paper Co.				Ticonderoga				
Effluent	ppq	18.0		150.0		CAL	FDUP	06/24/88
Effluent	ppq	24.0		160.0		CAL	FDUP	06/24/88
Pulp	ppt	16.0		103.0		WSU	LDUP	06/24/88
Pulp	ppt	17.0		108.0		WSU	LDUP	06/24/88
Pulp	ppt	31.0		185.0		WSU		06/24/88
Sludge	ppt	59.0		267.0		CAL	PRIM	06/24/88
Sludge	ppt	306.0		2470.0		CAL	SEC	06/24/88

U.S. EPA/ Paper Industry
Cooperative Dioxin Study

Analytical Results

Sample Matrix	Units	2378-TCDD Concentration	2378-TCDF Concentration	Lab	Comments	Sample Date
** State: OH						
* Mead Corporation			Chillicothe			
Effluent	ppq	3.0 ND	11.0	WSU		10/18/86
Pulp	ppt	0.6 ND	15.0	WSU		10/18/86
Sludge	ppt	3.3	39.0	WSU	COMB	10/18/86

U.S. EPA/ Paper Industry
Cooperative Dioxin Study

Analytical Results

Sample Matrix	Units	2378-TCDD Concentration	2378-TCDF Concentration	Lab	Comments	Sample Date
** State: OR						
* Boise Cascade Corp.			St. Helens			
Effluent	ppq	22.0	100.0	CAL		02/24/89
Pulp	ppt	4.2	12.0	CAL	LDUP	06/27/88
Pulp	ppt	4.4	11.0	CAL	LDUP	02/24/89
Pulp	ppt	6.5	18.0	CAL		02/24/89
Sludge	ppt	4.2	25.0	CAL		02/24/89
* James River Corp.			Clatskanie			
Effluent	ppq	15.0	120.0	WSU		09/10/86
Pulp	ppt	11.0	61.0	WSU		09/10/86
Sludge	ppt	19.0	100.0	WSU	PRIM	09/10/86
Sludge	ppt	89.0	810.0	WSU	SEC	09/10/86
* Pope & Talbot, Inc.			Halsey			
Effluent	ppq	30.0	82.0	CAL		06/27/88
Pulp	ppt	10.0	41.0	WSU		06/27/88
Sludge	ppt	31.0	106.0	CAL		06/27/88

U.S. EPA/ Paper Industry
Cooperative Dioxin Study

Analytical Results

Sample Matrix	Units	2378-TCDD Concentration		2378-TCDF Concentration		Lab	Comments	Sample Date
** State: PA								
* Appleton Papers, Inc.				Roaring Springs				
Effluent	ppq	11.0	ND	18.0		CAL		06/26/88
Pulp	ppt	1.0		21.0		CAL		06/26/88
Sludge	ppt	5.0		113.0		CAL	COMB	06/26/88
* International Paper Co.				Erie				
Effluent	ppq	24.0		68.0		CAL		06/19/88
Pulp	ppt	6.4		22.0		WSU		06/19/88
Sludge	ppt	1.4	ND	3.0		CAL	LDUP	06/19/88
Sludge	ppt	0.9		3.1		CAL	LDUP	06/19/88
* P.H. Glatfelter Co.				Spring Grove				
Effluent	ppq	8.4	ND	26.0		CAL		10/28/88
Influent	ppq	65.0		210.0		CAL		10/28/88
Pulp	ppt	3.9		13.0		CAL	LDUP	10/28/88
Pulp	ppt	6.5		18.0		CAL	LDUP	10/28/88
Pulp	ppt	0.4		2.2		CAL		10/28/88
Sludge	ppt	93.0		238.0		CAL		10/28/88
Penntech Papers, Inc.				Johnsonburg				
Effluent	ppq	6.8	ND	14.0		CAL		08/01/88
Effluent	ppq	9.7		65.0		CAL		08/01/88
Pulp	ppt	3.1		38.0		WSU		08/01/88
* Procter & Gamble Co.				Mehoopany				
Effluent	ppq	9.7	ND	2.8		CAL		07/06/88
Pulp	ppt	2.0		1.1		WSU		07/06/88
Sludge	ppt	2.3		0.0	NQ	CAL	LDUP	07/06/88
Sludge	ppq	6.0		6.0		CAL	Non-dewatered	07/06/88
Sludge	ppt	0.3	ND	0.7			LDUP	07/06/88

U.S. EPA/ Paper Industry Cooperative Dioxin Study

Analytical Results

Sample Matrix	Units	2378-TCDD Concentration		2378-TCDF Concentration	Lab	Comments	Sample Date
** State: SC							
* Bowater Corp.				Catawba			
Effluent	ppq	24.0		42.0	CAL		06/17/88
Pulp	ppt	2.1		3.3	WSU		06/17/88
Sludge	ppq	620.0		880.0	CAL	Non-dewa tered	06/17/88
* International Paper Co.				Georgetown			
Effluent	ppq	640.0		1600.0	CAL	FDUP	07/16/88
Effluent	ppq	490.0		1500.0	CAL	FDUP	07/16/88
Pulp	ppt	9.2		38.0	WSU	FDUP	07/16/88
Pulp	ppt	10.0		41.0	WSU	FDUP	07/16/88
Pulp	ppt	1.9		7.7	WSU		07/16/88
Pulp	ppt	17.0		55.0	WSU	FDUP	07/16/88
Pulp	ppt	16.0		52.0	WSU	FDUP	07/16/88
Sludge	ppt	62.0		161.0	CAL		07/16/88
* Union Camp Corp.				Eastover			
Effluent	ppq	20.0		53.0	CAL		07/22/88
Pulp	ppt	0.4	ND	1.3	WSU		07/22/88
Pulp	ppt	2.4		5.6	WSU		07/22/88
Sludge	ppt	6.9		13.0	CAL		07/22/88

03/09/90

U.S. EPA/ Paper Industry
Cooperative Dioxin Study

Analytical Results

Sample Matrix	Units	2378-TCDD Concentration	2378-TCDF Concentration	Lab	Comments	Sample Date
** State: TN						
* Bowater Corp.			Calhoun			
Effluent	ppq	6.8 ND	5.5 ND	CAL		06/24/88
Pulp	ppt	7.7	53.0	WSU		06/24/88
Sludge	ppt	0.0 NQ	17.0	CAL	LDUP Non-dewa tered	06/24/88
Sludge	ppt	4.5	14.0	CAL	LDUP Non-dewa tered	06/24/88
* Mead Corporation			Kingsport			
Effluent	ppq	6.0	44.0	CAL		06/06/88
Pulp	ppt	1.5	26.0	WSU		06/06/88
Sludge	ppt	3.0 ND	25.0	CAL		06/06/88

U.S. EPA/ Paper Industry
Cooperative Dioxin Study

Analytical Results

Sample Matrix	Units	2378-TCDD Concentration		2378-TCDF Concentration		Lab	Comments	Sample Date
** State: TX								
* Champion International				Houston				
Effluent	ppq	0.0	NQ	86.0		CAL	LDUP	10/07/88
Effluent	ppq	0.0		11.0		CAL	LDUP	10/07/88
Effluent	ppq	5.5	ND	5.8	ND	CAL	LDUP	10/07/88
Pulp	ppt	4.9		6.8		WSU		10/07/88
Sludge	ppt	106.0		144.0		CAL		10/07/88
* Champion International				Lufkin				
Effluent	ppq	7.0	ND	7.0	ND	WSU		12/03/86
Pulp	ppt	1.0	ND	1.2	ND	WSU		12/03/86
Pulp	ppt	3.9		7.8		WSU		12/03/86
Sludge	ppt	17.0		32.0		WSU	PRIM	12/03/86
Sludge	ppt	36.0		78.0		WSU	SEC	12/03/86
Sludge	ppt	18.0		34.0		WSU		12/03/86
* International Paper Co.				Texarkana				
Effluent	ppq	13.0		43.0		CAL	FDUP	08/06/88
Effluent	ppq	18.0		44.0		CAL	FDUP	08/06/88
Pulp	ppt	7.1		51.0		WSU		08/06/88
Pulp	ppt	12.0		81.0		WSU		08/06/88
Sludge	ppt	71.0		1000.0		CAL	FDUP LDUP	08/06/88
Sludge	ppt	0.0	NQ	600.0		CAL	FDUP	08/06/88
Sludge	ppt	86.0		387.0		CAL	LDUP	08/06/88
* Simpson Paper Co.				Pasadena				
Effluent	ppq	0.0	NQ	1400.0		CAL		10/08/88
Effluent	ppq	250.0		730.0		CAL		08/14/89
Pulp	ppt	14.0		48.0		WSU	FDUP	10/08/88
Pulp	ppt	18.0		66.0		WSU	FDUP	10/08/88
Pulp	ppt	4.5		11.0		WSU		10/08/88
* Temple-Eastex, Inc.				Evadale				
Effluent	ppq	88.0		100.0		CAL		07/28/88
Pulp	ppt	1.9		9.6		WSU		07/28/88
Pulp	ppt	3.1		6.3		WSU		07/28/88
Pulp	ppt	7.8		22.0		WSU		07/28/88
Pulp	ppt	4.1		13.0		WSU		07/28/88
Sludge	ppt	16.0		49.0		CAL		07/28/88

U.S. EPA/ Paper Industry Cooperative Dioxin Study

Analytical Results

Sample Matrix	Units	2378-TCDD Concentration		2378-TCDF Concentration	Lab	Comments	Sample Date
** State: VA							
* Chesapeake Corp.				West Point			
Effluent	ppq	16.0		96.0	CAL		12/04/88
Pulp	ppt	8.3		14.0	CAL		12/04/88
Sludge	ppt	14.0		47.0	CAL		12/04/88
* Union Camp Corp.				Franklin			
Effluent	ppq	68.0		71.0	CAL		05/08/88
Pulp	ppt	1.1		2.1	CAL		05/08/88
Pulp	ppt	5.2		5.7	CAL	LDUP	05/08/88
Pulp	ppt	5.4		6.9	CAL	LDUP	05/08/88
Pulp	ppt	3.8		4.2	CAL		05/08/88
Pulp	ppt	3.2		3.6	CAL		05/08/88
Sludge	ppt	3.6		6.0	CAL	PRIM	05/08/88
* Westvaco Corp.				Covington			
Effluent	ppq	180.0		520.0	CAL	FDUP	07/19/88
Effluent	ppq	18.0	ND	173.0	TRI	FDUP	07/19/88
Effluent	ppq	12.0		132.0	TRI	FDUP	07/19/88
Pulp	ppt	13.0		105.0	WSU		07/19/88
Pulp	ppt	6.2		49.0	WSU		07/19/88
Pulp	ppt	5.9		19.0	WSU		07/19/88
Sludge	ppt	119.0		799.0	CAL		07/19/88

03/09/90

U.S. EPA/ Paper Industry
Cooperative Dioxin Study

Analytical Results

Sample Matrix	Units	2378-TCDD Concentration	2378-TCDF Concentration	Lab	Comments	Sample Date
** State: WA						
* Boise Cascade Corp.			Wallula			
Effluent	ppq	360.0	7500.0	CAL		07/15/88
Pulp	ppt	56.0	1380.0	WSU		07/15/88
Sludge	ppt	70.0	1490.0	CAL		07/15/88
* Georgia-Pacific Corp.			Bellingham			
Effluent	ppq	5.3 ND	840.0	CAL		07/22/88
Pulp	ppt	2.6 ND	449.0	WSU	FDUP	07/22/88
Pulp	ppt	3.5	409.0	CAL	FDUP	07/22/88
Sludge	ppt	19.0	584.0	CAL		07/22/88
* ITT-Rayonier, Inc.			Hoquiam			
Effluent	ppq	23.0	8.6	CAL		07/09/88
Pulp	ppt	0.6 ND	3.8	WSU		07/09/88
Sludge	ppt	4.8	25.0	CAL		07/09/88
* ITT-Rayonier, Inc.			Port Angeles			
Effluent	ppq	22.0	36.0	CAL		07/27/88
Pulp	ppt	0.6 ND	2.1	WSU		07/27/88
Sludge	ppt	47.0	65.0	CAL		07/27/88
* James River Corp.			Camas			
Effluent	ppq	0.0 NQ	160.0	CAL	LDUP	08/15/88
Pulp	ppt	0.2 ND	0.6	WSU		08/15/88
Pulp	ppt	0.3 ND	0.9	WSU		08/15/88
Pulp	ppt	12.0	152.0	WSU		08/15/88
Sludge	ppt	12.0	105.0	CAL		08/15/88
* Longview Fibre Co.			Longview			
Effluent	ppq	4.6 ND	57.0	CAL		06/29/88
Pulp	ppt	4.8	0.0 NQ	WSU	LDUP	06/29/88
Pulp	ppt	4.7	18.0	WSU		06/29/88
Pulp	ppt	4.4	28.0	CAL	LDUP	06/29/88
Pulp	ppt	4.7	26.0	CAL	LDUP	06/29/88
Sludge	ppt	69.0	437.0	CAL		06/29/88
* Scott Paper Co.			Everett			
Effluent	ppq	7.5 ND	29.0	CAL		07/17/88
Effluent	ppq	8.3 ND	2.6 ND	CAL		07/17/88
Pulp	ppt	0.3 ND	0.1 ND	WSU		07/17/88
Sludge	ppt	14.0	72.0	CAL		07/17/88
* Simpson Paper Co.			Tacoma			
Effluent	ppq	0.0 NQ	27.0	CAL	LDUP	10/29/88
Effluent	ppq	0.0 NQ	26.0	CAL	LDUP FDUP	10/29/88

U.S. EPA/ Paper Industry Cooperative Dioxin Study

Analytical Results

Sample Matrix	Units	2378-TCDD Concentration		2378-TCDF Concentration	Lab	Comments	Sample Date
Effluent	ppq	0.0	NQ	22.0	CAL	FDUP	10/29/88
Effluent	ppq	0.0		26.0	CAL	LDUP	10/29/88
Effluent	ppq	17.0		100.0	CAL		08/01/89
Pulp	ppt	12.0		38.0	WSU		10/29/88
Sludge	ppt	0.0	NQ	87.0	CAL	LDUP	10/29/88
Sludge	ppt	39.0		101.0	CAL	LDUP FDUP	10/29/88
Sludge	ppt	29.0		106.0	CAL	FDUP	10/29/88
Sludge	ppt	30.0		176.0	CAL		08/01/89
* Weyerhauser Co.				Cosmopolis			
Effluent	ppq	9.7		400.0	CAL		08/05/88
Pulp	ppt	1.0	ND	6.3	WSU	FDUP	08/06/88
Pulp	ppt	0.0	NQ	6.4	WSU	FDUP	08/06/88
Pulp	ppt	0.3	ND	3.1	WSU	FDUP	08/06/88
Pulp	ppt	0.3	ND	2.9	WSU	FDUP	08/06/88
Sludge	ppt	12.0		61.0	CAL		08/06/88
* Weyerhauser Co.				Everett			
Effluent	ppq	33.0		260.0	CAL		07/24/88
Pulp	ppt	3.4		16.0	WSU		07/24/88
Pulp	ppt	5.2		20.0	WSU		07/24/88
* Weyerhauser Co.				Longview			
Effluent	ppq	10.0		37.0	CAL	FDUP	08/02/88
Effluent	ppq	8.5		21.0	CAL	FDUP	08/02/88
Pulp	ppt	1.7		2.8	WSU	FDUP	08/02/88
Pulp	ppt	1.6		2.8	WSU	FDUP	08/02/88
Pulp	ppt	7.7		20.0	WSU		08/02/88
Pulp	ppt	1.7		9.4	WSU		08/02/88
Sludge	ppt	25.0		80.0	CAL	FDUP	08/02/88
Sludge	ppt	0.0	NQ	84.0	CAL	FDUP LDUP	08/02/88
Sludge	ppt	35.0		89.0	CAL	LDUP	08/02/88

U.S. EPA/ Paper Industry
Cooperative Dioxin Study

Analytical Results

Sample Matrix	Units	2378-TCDD Concentration		2378-TCDF Concentration		Lab	Comments	Sample Date
** State: WI								
* Badger Paper Mills, Inc.				Peshtigo				
Effluent	ppq	9.8		280.0		CAL	LDUP Pulp mill	07/22/88
Effluent	ppq	4.5		110.0		CAL	LDUP Pond	07/22/88
Effluent	ppq	6.4	ND	170.0		CAL	Pulp mill LDUP	07/22/88
Effluent	ppq	5.3	ND	130.0		CAL	Pond LDUP	07/21/88
Pulp	ppt	4.4		323.0		WSU		07/22/88
Sludge	ppq	36.0		1800.0		CAL	Non-dewa tered	07/22/88
* Consolidated Papers, Inc.				Wisconsin Rapids				
Effluent	ppq	49.0	ND	34.0	ND			03/21/87
Pulp	ppt	20.0		83.0		CAL	FDUP	03/21/87
Pulp	ppt	18.0		79.0		CAL	FDUP	03/21/87
Pulp	ppt	2.2	ND	12.0				03/21/87
Pulp	ppt	12.0		86.0			LDUP	03/21/87
Pulp	ppt	15.0		105.0			LDUP	03/21/87
Sludge	ppt	69.0		556.0			PRIM	03/21/87
Sludge	ppt	134.0		679.0			SEC	03/21/87
Sludge	ppt	54.0		330.0			COMB	03/21/87
* James River Corp.				Green Bay				
Effluent	ppq	11.0		61.0		CAL	TO RIVER LDUP	08/22/88
Effluent	ppq	8.5	ND	29.0		CAL	TO MSD	08/22/88
Effluent	ppq	19.0		72.0		CAL	LDUP FDUP	08/22/88
Effluent	ppq	15.0		54.0		CAL	FDUP	08/22/88
Pulp	ppt	0.8	ND	7.1		WSU		08/22/88
Sludge	ppt	35.0		250.0		CAL		08/22/88
* Nekoosa Papers, Inc.				Nekoosa				
Pulp	ppt	22.0		283.0		WSU		06/17/88
* Nekoosa Papers, Inc.				Nekoosa & Port Edwards				
Effluent	ppq	40.0		320.0		CAL		06/17/88
Sludge	ppt	109.0		1300.0		CAL		06/17/88
* Nekoosa Papers, Inc.				Port Edwards				
Pulp	ppt	0.4	ND	4.1		WSU		06/17/88

U.S. EPA/ Paper Industry Cooperative Dioxin Study

Analytical Results

Sample Matrix	Units	2378-TCDD Concentration		2378-TCDF Concentration		Lab	Comments	Sample Date
* Pentair, Inc.				Fark Falls				
Effluent	ppq	5.4	ND	4.8		CAL		07/04/88
Pulp	ppt	0.5	ND	0.9	ND	WSU		07/04/88
Sludge	ppt	9.4		90.0		CAL	LDUP	07/04/88
Sludge	ppt	11.0		73.0		CAL	LDUP	07/05/88
* Wausau Paper Mills Co.				Brokaw				
Effluent	ppq	4.2	ND	14.0		CAL	LDUP	07/22/88
Effluent	ppq	4.9	ND	2.1	ND	CAL	LDUP	07/22/88
Pulp	ppt	0.4	ND	9.9		WSU		07/22/88
Sludge	ppt	3.2		68.0		CAL	LDUP	07/22/88
Sludge	ppt	4.1		56.0		CAL	LDUP	07/22/88
* Weyerhauser Co.				Rothchild				
Effluent	ppq	12.0		24.0		CAL	LDUP	08/12/88
Effluent	ppq	12.0		18.0		CAL	LDUP	08/12/88
Pulp	ppt	15.0		26.0		WSU		08/12/88
Sludge	ppt	58.0		150.0		CAL		08/12/88